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Some Engineering Details  
of Military Aviation

Electrical Engineering

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SOME ENGINEERING DETAILS OF MILITARY AVIATION

BY

TOWNSEND FOSTER DODD

B. S. University, of Illinois, 1907

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THESIS

Submitted in Partial Fulfillment of the Requirements for the

Degree of

ELECTRICAL ENGINEER

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1915



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066

UNIVERSITY OF ILLINOIS  
THE GRADUATE SCHOOL

May 15, 1915

I HEREBY RECOMMEND THAT THE THESIS PREPARED BY

Townsend Foster Dodd

ENTITLED Some Engineering Details of Military Aviation

BE ACCEPTED AS FULFILLING THIS PART ON THE REQUIREMENTS FOR THE

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# ILLUSTRATIONS.

Plate		After page
1	Air Speed Indicator, Propeller Details.....	18
2	Air Speed Indicator, Calibration Curves.....	19
3	Air Speed Indicator, Angular Variations.....	19
4	Renault Motor, Original Housing.....	22
5	Renault Motor, Original Housing.....	22
6	Renault Motor, Improved Housing.....	23
7	Renault Motor, Improved Housing.....	23
8	Method of Operation, Bomb-Dropping Device.....	39
9	Bomb-Dropping Fire-Control Device.....	44
10	Bomb-Dropping Fire-Control Device.....	44
11	Bomb-Dropping Fire-Control Device.....	44
12	Angle-of-Sight Curves, Bomb-Dropping Fire-Control Device..	44
13	Effect of Projectile.....	45
14	Method of Carrying Projectiles.....	45
15	Channel Buoy.....	52
16	Channel Buoy, Details.....	52
17	Channel Buoy, Details.....	52
18	Channel Buoy, Details.....	52



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## SOME ENGINEERING DETAILS OF MILITARY AVIATION.

### CHAPTER 1.

#### DEFINITIONS.

Aviation is a new science, and like all other new phases of human endeavor it has added new words to the language and has given new meanings to old ones. It is therefore deemed advisable to give the definitions of the aviation terms used in this thesis.

**ANGLE OF INCIDENCE:-** The angle an aeroplane surface makes with the direction of motion relative to the air. The angle is measured between the chord of the surface and the direction of air motion.

**BANK:-** The raising of the outer wing for turning.

**BIPLANE:-** An aeroplane with two superimposed surfaces or wings; a "double-decker."

**CAMBER:-** The slight convexity of the upper face of an aeroplane surface. Also the concavity of the lower face. Camber is usually measured in terms of height above the chord.

**CHORD:-** The straight lines joining the ends of a fore and aft cross-section of an aeroplane wing or other aeroplane surfaces.

**DRIIFT:-** The component of the total pressure upon an aeroplane surface, due to its motion relative to the air, that opposes the motion. (See Lift).

**FUSELAGE:-** The main frame of an aeroplane, its covering and interior members; that part which usually contains the engine, crew, tanks, etc., and to which the wings and other organs are attached.



## TABLE OF CONTENTS.

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CHAPTER I.	Page
Definitions.....	1
CHAPTER II.	
Aeroplanes in General.....	3
CHAPTER III.	
Special Military Requirements.....	6
CHAPTER IV.	
A Safety Device.....	12
CHAPTER V.	
Engine Improvements.....	22
CHAPTER VI.	
Wireless Telegraphy.....	32
CHAPTER VII.	
Aggressive Weapons.....	38
CHAPTER VIII.	
Attack Upon Fortified Harbors.....	48
CHAPTER IX.	
Field Shop.....	57



LIFT:- The component of the total pressure upon an aeroplane surface, due to its motion relative to the air, that acts upward at right angles to the direction of motion. The sustaining force. (See Drift.)

LONGERONS:- The longitudinal timbers of the fuselage.

PUSHER:- An aeroplane with the propeller, or propellers, in rear of the main planes, or wings.

TRACTOR:- An aeroplane with the propeller, or propellers, in front of the wings.



## CHAPTER 11.

## AEROPLANES IN GENERAL.

In order to understand the conditions governing the flight of heavier-than-air craft, the following should be kept in mind:-

1. Air has weight. (The weight of a cubic foot of air at sea-level, under normal temperature and density conditions, is approximately .08 pounds, or the weight of 12.4 cubic feet of air is one pound.)

II. As air has weight, it requires the application of a force to set it in motion, and, when in motion, it requires the application of a force to change its direction or its velocity.

III. If a force act to change the state of a body of air with respect to rest or motion, the body of air will offer a resistance equal and directly opposed to the force.

IV. The resistance offered by the air to bodies moving through it, will vary as functions of the speed, size, shape, and smoothness of surface, of the bodies.

The first and fourth statements are based upon laboratory tests and theory. The second and third are from Newton's Laws of Motion, which have been tested in countless experiments, and are universally accepted as being correct.

Newton also stated the following law for the pressure exerted by a wind upon a flat surface placed at an angle of ninety degrees to the direction of the air current,  $P_0 = K S V^2$ ,  $P_0$  = pressure in pounds,  $K$  = an experimental constant (now given as .0030),  $S$  = area of surface, in square feet,  $V$  = velocity of the wind, in miles per hour. This formula still forms one of the fundamental equations of aero-dynamics and is in constant use.

Newton, however, stated another "law" to express the pressure normal to the surface, exerted by an air-stream, upon a flat plate placed at the angle



" $\alpha$ " with the direction of the air current. The reputation of the great scientist was sufficient to prevent the "law" being seriously questioned until the middle of the nineteenth century. This "law" was expressed by the formula,  $P_{\alpha} = KSV^2 \sin^2 \alpha$ , in which  $P_{\alpha}$  = pressure normal to the surface, and  $\alpha$  = the angle between the air-stream and the surface.

When efforts were first made to design heavier-than-air craft, using the upward reaction upon planes of the displaced air for the sustaining force, this "law" was used to calculate the area of the surface required. The calculations proved that for speeds less than 100 miles per hour the area required would be greater than it was possible to construct with the materials available. Some engineers even went so far as to state that some of the heavier soaring birds obtained their power of soaring flight through some mysterious means. A great many suggestions were offered and seriously considered as to the means used by the birds. In the light of present knowledge some of the theories then advanced are laughable. One investigator went so far as to present an idea that the feathers upon the upper part of the wings were oscillated so rapidly as to drive the air away from the upper surface, thus creating a partial vacuum. The unbalanced pressure of the air beneath the wing would then supply the sustaining force. A great many birds were dissected in attempts to discover the muscles that oscillated the feathers. Laboratory experiments made in the latter part of that century upon inclined surfaces proved Newton's "law" to be wrong, and the surprising discovery was made that the pressure exerted normal to the direction of flow, by the air flowing past an inclined surface, was, at some angles of incidence, greater than the pressure exerted in the direction of flow, upon the same surface when placed normal to the air-stream.

M. Eiffel, the noted French physicist, states that he has determined, experimentally, that the "lift" upon a flat plate one meter square is approxi-



mately 1.4 times as great when it is placed at an angle of 38 degrees with the air-stream than it is when the plate is placed normal to the current, for all velocities between thirty and ninety miles per hour.

Experiments with curved surfaces have proved that it is possible to obtain a lift of five pounds per square foot at velocities less than forty miles per hour. With the materials available it was practicable to construct sufficiently strong aeroplanes with a lifting surface of 400 square feet, not weighing more than 800 pounds. The improvement of the internal combustion engine supplied the necessary light and powerful motor to drive the machine with the required velocity, and heavier-than-air flight became a reality.

After the historic flights by the Wrights in 1908, both in America and Europe, the science of aerial navigation has advanced rapidly, and in the laboratory, workshop, and field, the progress has been very satisfactory.



## CHAPTER 111.

## SPECIAL MILITARY REQUIREMENTS.

The military value of the aeroplane is at present greater than the commercial, and as the conditions of the military service are learned efforts to meet those conditions are made. The military service demands, not only specially designed machines, but also a great number of special instruments and devices that are not required for aviation use under peace conditions. The military pilot can not select the country over which to fly but must go wherever the occasion demands. His choice of fields for starting and landing will not be governed by his desires, but will be limited to those that satisfy the military necessities. He must expect to be forced to use a very small space, and the machines must be designed to successfully meet this requirement. In order to be able to ascend rapidly from a restricted area and quickly to gain a height where the danger from the enemy's fire is minimized, the aeroplane must have the ability to climb rapidly.

For cross-country work, especially over strange territory, the machine should be able to glide for a long distance without power, so that in case of motor trouble, the pilot will have a large area from which the landing place may be selected.

It has been determined that under rough air conditions, over strange country, the pilot will be fully occupied in flying the machine and will not be able to do accurate military observing, so it is necessary to have a machine that is capable of carrying two men; one to do the piloting, and the other, the observing and reporting.

To lessen the danger of the aeroplane being wrecked in case the pilot is disabled by the enemy's fire, or from any other cause, and to permit him to rest, dual controls must be provided and arranged so that either of the men can fly the machine. These controls must be connected in such a manner



that either one can be disconnected quickly and easily to prevent mishap in case one of the men is killed or becomes unconscious.

As the aeroplane can dodge the enemy's troops by flying over them at a safe height access to important and vulnerable points may be gained, and, if provided with a means of destroying bridges, arsenals, depots, etc., in the enemy's rear, very important results may be obtained. As such points will usually be well guarded it may not be possible for the flyers to land and place the explosives, or to fire the objects attacked, but the destruction must be accomplished while the aeroplane remains at a safe height. This requires some device for accurately placing the explosives or incendiary missile.

It has been found that underwater objects are visible from a sufficient altitude and the military aeroplane is forced to adapt itself to naval warfare, as well as to the battles on land. Submarine vessels, mines, torpedoes, and ship-channels, are visible to the flyer, and he becomes the "eyes of the navy" as well as of the army.

Day after day, new uses for the military "birdman" are discovered, and his equipment is constantly being modified, changed, and improved, to meet the new requirements.

Some of the conditions governing the military uses of the aeroplane, as distinguished from the commercial or sporting use, have been briefly outlined. The most important item of any aeroplane, for either civil or military use in cross-country work, is the power plant. Flight over wooded, mountainous, or hostile country demands that the engine be as nearly absolutely reliable as human skill can build it. As long as the engine delivers full power to the propeller there is very little danger to the aviator if he is experienced, and if his altitude is more than one thousand feet above the ground. The modern aeroplane is built sufficiently strong to safely combat any air conditions that are not cyclonic, and an aeroplane in the hands of an expert



will be able to fly safely in weather that would be dangerous for the majority of the smaller steam and sailing ships. Unfortunately the weight of the aeronautical motor is limited to such a great extent that all parts have to be so light that it is not possible to obtain anything near the desired reliability. The earlier aeroplane engines were designed with an extremely small factor of safety; it being impossible with the materials available to obtain a sufficiently powerful engine, with the proper factor of safety, without excessive weight. The most pronounced advance in aviation within the last three years has been along the lines of engine development. The chemists and metallurgists have furnished the designers with materials whose qualities were unknown ten years ago. Shafts, rods, gears, pistons, and in some cases, the cylinders, are made of special steel alloys, heat-treated to produce the desired qualities. In connection herewith, the steel alloy used for connecting-rods of some aeronautical engines has an ultimate tensile strength of 240,000 pounds per square inch, and is tough enough to successfully withstand the vibration without crystallizing. Crank-cases are made of aluminum alloys or of special steels. The result is still far from satisfactory, although the progress that has been made is a source of great encouragement.

As all engines are liable to failure, the military aeroplane must be capable of gliding for a long distance so that a suitable landing place may be reached. This quality is dependent upon the head resistance of the machine, its weight, the lifting power of the surfaces, and the aerodynamical ratio of lift to drift. The aeroplane designer attempts to obtain the desired result by shaping the portions of the machine that are exposed to the air in such a manner that the resistance will be a minimum. All other parts are designed, as far as practicable, for the greatest strength with the least weight. Beams are made hollow, or with the familiar "I" section; struts are made hollow and tapered; some of the wooden parts are made up of thin laminations glued



together; the most suitable materials of all types are selected: silver spruce, mahogany, second-growth ash and hickory, rock-elm, and cotton-wood, are used for the wooden portions of the frame-work; while special high-grade steel wires and the best of Irish linen cloth are used for the tension members and the covering fabric.

Countless tests have been made to determine the best shapes and proportions for the wings, fuselage, and tail.

The result of the military demand for a good gliding machine has been the production of aeroplanes, which with a useful load of 450 pounds in addition to fuel and oil for four hours flight, is able to travel ten feet horizontally for each foot vertically. With a machine of this type, at an altitude of 5000 feet, in case the engine failed a landing could be made at any point within a circle four miles in diameter, if there was no wind.

In order to be able to rise from a restricted area, power in excess of that needed for level flight is necessary to furnish the required acceleration. The aeroplane's ability to fly at a low speed is as important, in this connection, as excess power, for with two machines of the same weight and power, if one can fly at thirty miles per hour while the other requires a speed of sixty miles per hour, the former will be able to climb out of a much smaller field than the latter. The ability to fly at slow speed is also desirable when it is necessary to land in a small field or in soft or broken ground. In making a landing under any of the above conditions, the pilot will handle the machine so that it will not have sufficient speed to sustain itself in the air by the time it has arrived at a height of one or two feet above the ground, and drops this distance. The distance that a machine runs after touching the ground will, of course, depend upon the horizontal component of its velocity at the moment of contact, and if one machine can be landed at a speed of thirty miles per hour it will come to rest within a shorter distance than another machine



that has to be landed at sixty miles per hour. The tendency to over-turn in rough or soft ground will also be much less in the case of the slower aeroplane. The ability to travel at high speed is a very desirable military feature. Unfortunately there has, as yet, been no wing section evolved that is well adapted for both high and low speeds, so a compromise has been made by providing air-brakes which are to be operated at the moment of contact with the earth. The most successful type of air-brakes is the one that rotates a portion of the wing or an auxiliary surface so that it will be presented at an angle of 60 or more degrees to the direction of travel. The higher that the air-brake surface is placed the greater will be the moment of the force that tends to prevent over-turning.

To meet the naval requirements the hydro-aeroplane and the flying boat have been evolved. The former is simply an aeroplane mounted upon a float instead of upon wheels, while the latter consists, primarily, of a boat-like body to which aeroplane surfaces are attached, the machine being driven by an air propeller.

In 1914, the aeroplane industry in America had advanced to the state where the following specifications were deemed reasonable requirements that had to be met before a machine could enter a competition for military aeroplanes for the United States Army.

"The type desired, namely, a military reconnoissance aeroplane, must possess the following characteristics:- Biplane, inclosed fuselage, two-seater, dual control, and have a maximum speed not less than 70 and a minimum speed of not more than 40 miles per hour when carrying fuel and oil for four hours' flight at 70 miles per hour and a useful load of 450 pounds, and under these conditions of load to climb 4000 feet in 10 minutes. The power plant to be located in front of the occupants and suited to the requirements of the aeroplane. The motor must be capable of throttling to 20 per cent of



full speed and running without overheating over the land.

The propeller or propellers to be of efficient form and construction and suited for the particular machine and possessing a minimum efficiency of 70 per cent.

The maximum gliding angle shall under no condition exceed 1 on 6; that is to say, 1 foot drop for each 6 feet of advance.

No part shall be of such length that when packed in its case the case shall exceed 20 feet in length. "



## CHAPTER IV.

## A SAFETY DEVICE.

The aeroplane pilot must be able to balance his machine laterally, longitudinally, and to steer from side to side. In addition to these duties he must also control the speed of his engine. The locomotive driver has to deal with the last point only as the tracks do the steering. An automobile driver controls both engine speed and the direction of travel, in one plane only. The motorcyclist must maintain lateral balance as well as horizontal direction and speed. None of these, however, need to consider longitudinal balance, and none of these travel upon a freely moving surface which is never at rest, and which is invisible. Moreover, the locomotive driver, the chauffeur, and the motorcyclist, can learn the operation of their machines while travelling at slow speeds, and in case of mistakes and errors at low speed, the injury to the driver and machine will be probably very slight. In the case of the air-pilot it is impossible to start training at extremely slow speeds, for in order to be able to fly, the modern aeroplane must attain a speed of about thirty miles per hour, as the minimum, and as the skill required to fly a machine at its slowest speed is much greater than that necessary to fly the same aeroplane at a more rapid rate, a sufficiently large margin of safety should be maintained.

The method in general use for instructing pilots is to train them in a dually controlled machine. The instructor first carries the student as a passenger upon flights so that the beginner may become accustomed to being up in the air. After the strangeness has worn off the student is permitted to control the lateral balance only, the instructor using the duplicate control lever to prevent dangerous mistakes. After proficiency has been attained upon one control the pupil is given the others, one by one, until he becomes able to handle the machine in the air. As speed is the most important single



factor of safe flying, the throttle is the last control placed under the student's jurisdiction. After he has become proficient he is permitted to fly alone, and at this stage of his training the danger is the greatest. The air conditions are never exactly the same on different days; different motor troubles will be encountered, and the thousand and one incidents that make aviation a dangerous pursuit will occur. Some of the conditions will have been met and the remedies learned, while with the instructor, but new situations constantly arise. One of the gravest dangers is that due to loss of air speed, from any cause. The student's experience is not sufficient to warn him quickly enough, especially if there are other factors demanding his attention. In an effort to minimize this danger several devices have been constructed for indicating the actual speed of an aeroplane through the air.

The necessity of an air speed indicator is made imperative by the fact that people have become accustomed to judging the speed of moving objects by noting the rapidity with which other objects are passed. As the air is not visible the inexperienced aviator is very liable to forget, that, although he may be travelling very rapidly over the earth, his progress through the air may be so slow that the aeroplane is in great danger of falling.

If a body be placed in a current of air, the air exerts a pressure upon it. The amount of the pressure per square unit of cross-section of the body normal to the direction of the air-stream varies as functions of the density and the velocity of the air, and also as functions of the shape and size of the body. For a body of a given shape and size the total pressure will vary as functions of the air density and velocity. If the variations of the air density are small, the variations in the pressure may be considered as due entirely to the variations in velocity. It thus becomes possible to measure the pressure exerted by the air upon a selected body, and to express this pressure in terms of velocity.



The instruments commonly used for measuring air velocities are pitot tubes and the hemi-spherical-cup anemometer. Both of the above named instruments have been used to determine the air speed of aeroplanes but neither have proved satisfactory.

In an effort to obtain a more suitable instrument for aviation work, a French firm patented an air speed indicator consisting of a flat pressure-plate held at right angles to the longitudinal axis of the aeroplane, and acting upon a calibrated spring. This plate was mounted upon a rod carried by a double-link suspension, so that the face of the plate, throughout its limits of travel, remained normal to the longitudinal axis of the aeroplane. The amount of movement was registered by a pointer moving over a scale graduated to show the speed in miles per hour. This instrument, although crude, inaccurate, and with a very grave defect, was so much more easily mounted than the pitot tubes or cup anemometer, that it became popular with foreign aviators. This device, as commonly built and used, is very dangerous for a beginner in flying to depend upon, for unless it is mounted upon a universal joint, free to swing in all directions and with a horizontal as well as a vertical vane, so that the pressure-plate will always be held at right angles to the line of flight, the velocities indicated will be inaccurate.

Due to the fact that a beginner very often fails to fly so that the longitudinal axis of his machine is kept parallel, or tangent, to the path of flight, the pressure-plate will, if not mounted upon an universal joint, be turned at an angle less than ninety degrees with the air current, and the pressures resulting upon the plate usually will be greater than the pressures that would be exerted upon the plate if same was kept normal to the air-stream.

Beginners, as a general rule, do not like to bank the aeroplane enough to make a proper turn. The tendency is to keep the wings level and to make the turn with the use of the rudder only. The result is a skidding turn, the



centrifugal force causing the machine to slide sidewise, away from the center. Cases often occur where the longitudinal axis of the aeroplane makes an angle of as many as thirty degrees with the tangent to the line of flight, and sometimes the skidding is so pronounced that it is believed that the angle between the longitudinal axis of the machine and the tangent to its path becomes as great as sixty degrees.

If the pressure plate is fixed normal to the longitudinal axis of the machine (the usual way of mounting), the plate will be presented at an angle varying between ninety and thirty degrees. If the plate is square, with an area of one square foot, at a speed of sixty miles per hour, the pressure on the plate, when normal to the air-stream, will be, from Eiffel's experiments, expressed by the equation,  $P_{90} = K_{90} S V^2$ , where  $K_{90} = .0030$ ,  $S = 1$ ,  $V = 60$ , and  $P_{90} = 10.8$  pounds. If the instrument be calibrated so that a pressure of 10.8 pounds gives a reading of 60 miles per hour, and the aeroplane is permitted to skid at an angle of thirty degrees from its proper path, the plate will be presented to the air-stream at an angle of sixty degrees, and the value of the constant "K" will change from .0030 to .0031. If the velocity of the machine through the air does not change the reading will be three per cent greater than the actual speed. The component of the actual velocity that is parallel to the longitudinal axis of the machine is the only part of the total velocity that can be utilized for sustentation, and the value of this component will be the total velocity multiplied by the cosine of thirty degrees, or in the case assumed, it will be  $60 \times .866$ , or 52 miles per hour, while the instrument reading will be 61.8 miles per hour. If the skidding should be as great as fifty-five degrees from the proper path, the value of "K" will change from .0030 to .0042, and the reading will be forty per cent greater than the actual speed, or 84 miles per hour; while the velocity that is supplying the sustaining force will be only, sixty multiplied by the cosine of fifty-five degrees,



or 60 x .57, or 34 miles per hour.

The minimum speed of the machine would in the latter case have to be less than 34 miles per hour, or control would be lost, and unless the machine was three or four hundred feet or more from the earth, an accident would be sure to result. If at a sufficient altitude, the speed generated by the fall would enable the pilot to regain control, provided the inexperienced flyer remained cool and calm under such extremely trying circumstances.

(In the above examples, some minor aero-dynamical corrections have been omitted, as they do not materially change the results.)

The pitot tube air speed indicator is subject to the same defect, but as usually mounted, to a smaller degree. On account of the mechanical difficulties, it is extremely hard to mount the tubes so that the openings will be outside of the area effected by the propeller-blast in the tractor type aeroplane.

The cup type anemometer is difficult to mount so that it will be unaffected by the propeller-blast, and still be in a position where it can easily be read. It is also too delicately constructed to withstand the rough usage to which it would be subjected on an aeroplane.

From experiments made in America and Europe it has been determined that curved surfaces can be constructed so that the values of "K" will vary (within certain limits), very nearly as the cosine of the angle with which the surface is presented to the air-stream. In October, 1913, Lieut. H. M. Kelly, U. S. A. suggested that for the flat pressure-plate of the instrument described above a curved surface might be devised, so that the resultant pressure normal to the surface, at varying angles of incidence, would vary directly as the component of the velocity normal to the surface. He started the construction of an instrument based upon this assumption but before the same was completed Lieut. Kelly was killed in an aviation accident. In November, 1913, the author attempted to complete the device, but as the notes and sketches made by Lieut.



helly were not available it was found impossible to carry out the idea in a satisfactory manner, using a pressure-plate balanced by a calibrated spring. The idea then was considered of using the ordinary cup anemometer with an auxiliary vertical vane. The anemometer was free to rotate about a vertical axis, as the vane swung so as to align itself with the air-stream, and the rotation of the anemometer caused a relative movement of the index on the dial, and compensated for the difference between the velocity of the aeroplane along its path, and the velocity component that was parallel to the longitudinal axis of the machine. Although this idea was correct from the theoretical standpoint, the difficulties in construction and mounting and the lack of sturdiness of the anemometer, caused it to be abandoned. It was found, however, that the magnetic indicator of the anemometer was well adapted for this type of work on account of the small and uniform friction resistance of the moving parts.

An effort was made to combine the curved surface suggested by Lieut. Kelly with the magnetic indicating device of the anemometer. This was accomplished by making up the curved surface in the form of a screw propeller, which was mounted upon and drove the indicator-shaft. The shape of the propeller surfaces was designed for fixed mounting, parallel to the longitudinal axis of the aeroplane. To obtain a basis for the design of the propeller, the indicator-shaft was rotated at varying speeds, and a curve showing the R. P. M. and the corresponding miles per hour readings was plotted. A two bladed propeller was then designed with a pitch calculated to give the proper R. P. M. at the different air speeds. The instrument was mounted upon the handle-bars of a motor-cycle equipped with an accurately calibrated speedometer, and tested at speeds varying between ten and forty miles per hour. The instrument was found to read too low, the error increasing with the speed. Another propeller of slightly less pitch was constructed and adjusted by chang-



ing the curve of the back of the blade until the instrument was accurate at thirty miles per hour, when held with the axis parallel to the air-stream. The indicator then was checked at different speeds, and it was found that as the speed increased above thirty miles per hour the readings were low, and that below thirty miles per hour the readings were too high. This variation was believed to be due to the friction caused by the thrust of the propeller, and a new one was constructed with much flatter camber on the back and face in an attempt to increase the lift to drift ratio. The following indicates the method of design, and is simply an adaptation of the method usually followed in designing the propellers for flying machines.

With good design, a slip of ten per cent is the usual amount that occurs. From tests of the anemometer-indicator, a speed of 364 R. P. M. gave a reading of thirty miles per hour. The Bleriot type of wing section was selected on account of the high lift to drift ratio, and the correspondingly small friction due to thrust. This section also is strong and easily built. As the minimum safe flying speed of the machine upon which it was desired to use the indicator was about thirty miles per hour, this value was regarded as the most important one. From tests with the propeller first built it was known that an effective face area of six square inches would furnish sufficient power to drive the magnetic indicator. As approximately  $1\frac{5}{8}$ " of the propeller's length which formed the hub, would be ineffective, a length of blade of  $7\frac{5}{8}$ " was assumed. The circumference of the circle described by the ends of the blade was then 23.95", or approximately 2 ft. To determine the pitch, i.e., the distance along the axis of rotation that would be travelled through during one revolution, the following calculations were made;

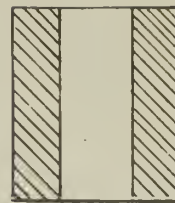
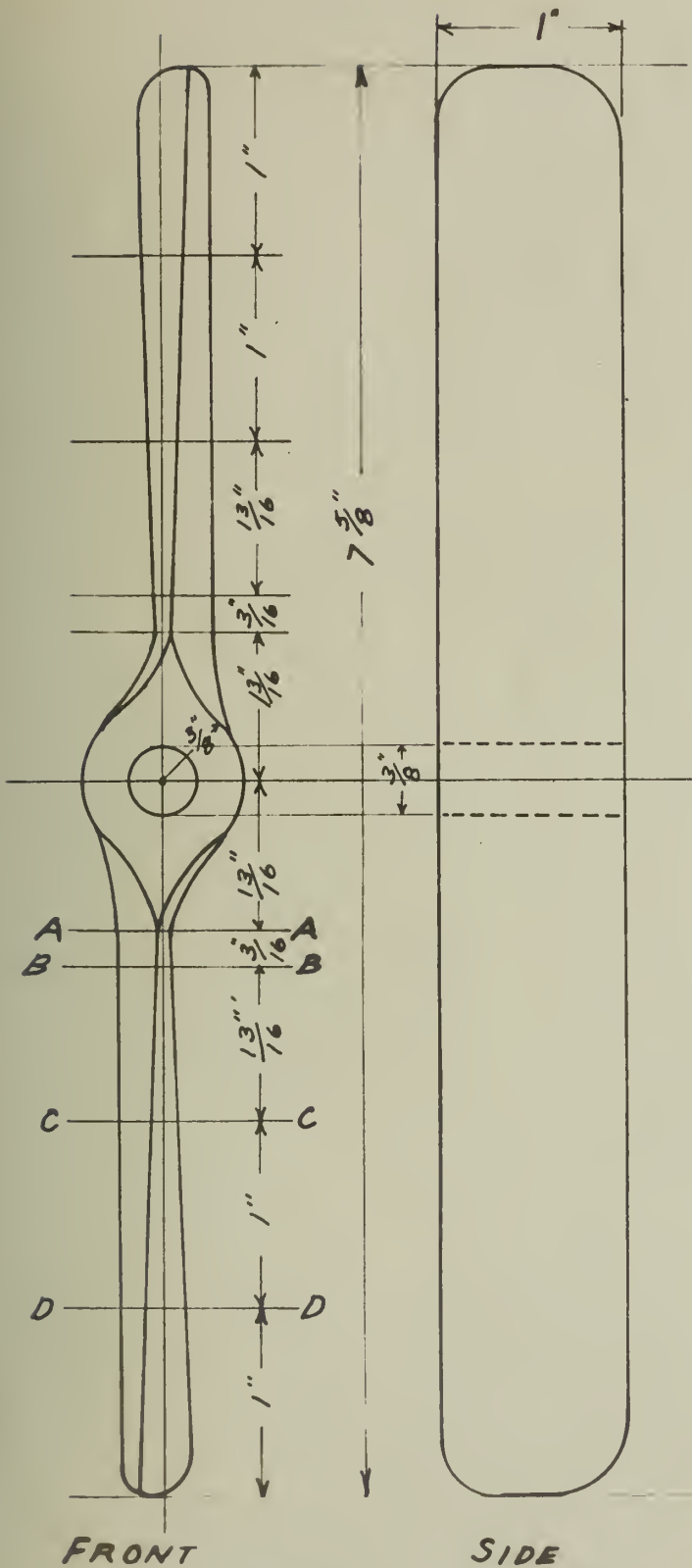
$$30 \text{ M. P. H.} = 2640 \text{ feet per minute.}$$

From tests, 364 R. P. M. gave reading of 30 M. P. H.

$$2640 \div 364 = 7.25 \text{ feet, the net pitch of the blade.}$$



(To follow page 18).



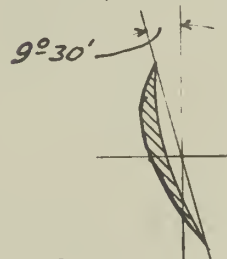
SECTION THROUGH HUB.



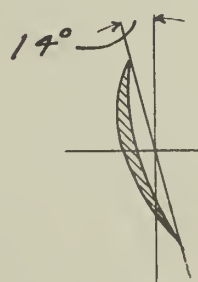
SECTION A-A



SECTION B-B.



SECTION C-C



SECTION D-D.

PLATE NO. 1.  
AIR-SPEED INDICATOR  
PROPELLER DETAILS.  
Material - Second-growth ash.  
1 Required.



Allowing ten per cent for slip, the gross pitch  $= 7.25 \times 90 = 6.52$  feet.

Then the circumference, 2, divided by the pitch equals the tangent of the angle between the face of the blade, at the tip, and a line parallel to the axis, equals .307, or  $\tan^{-1}.307 = 17$  degrees.

As it was desired to maintain a constant pitch from hub to tip, the angles at the hub ( $13/16$ " from the axis), and at distances of 1, 2, and 3 inches from the axis were calculated in the same manner, and found to be 4, 6,  $9\frac{1}{2}$ , and 14 degrees, respectively. These angles were laid off upon brass sheets, and correspond to the chords of the face at the different points, as indicated on Plate No. 1. The brass was trimmed to the chord-lines, and then bent to the radius corresponding to its distance from the center of the propeller. The piece of wood selected for the blade was very carefully sawed at the datum marks, and the waste wood removed, until the chord edge of the plates fitted the surface thus made. Similiar plates were made for the back surfaces of the blade. A steel scraper was then made to correspond to the curve desired for the face. Sheet brass gauges were also cut for the face and back curves, and bent to the proper radii. These were used to check the work. For convenience in working, the hub had been drilled before blades were shaped. This hole was reamed to a drive-fit after blades were finished and trued. Propeller was then mounted, and instrument calibrated. Calibration curve No. 1, Plate No. 2, was obtained. To correct the instrument, the curve of the back of the blades was flattened slightly, and curve No. 2, Plate No. 2, resulted. These two curves were obtained upon a motorcycle, the instrument being mounted upon the handle-bars. The indicator was then mounted upon an aeroplane, and curve No. 3, Plate No. 2, obtained, the aeroplane being flown straight and level over a measured course; speed taken by stop-watch. Altitude of flight about ten feet above the ground. When tested on the motorcycle there was no wind, the weather being clear and calm. The readings



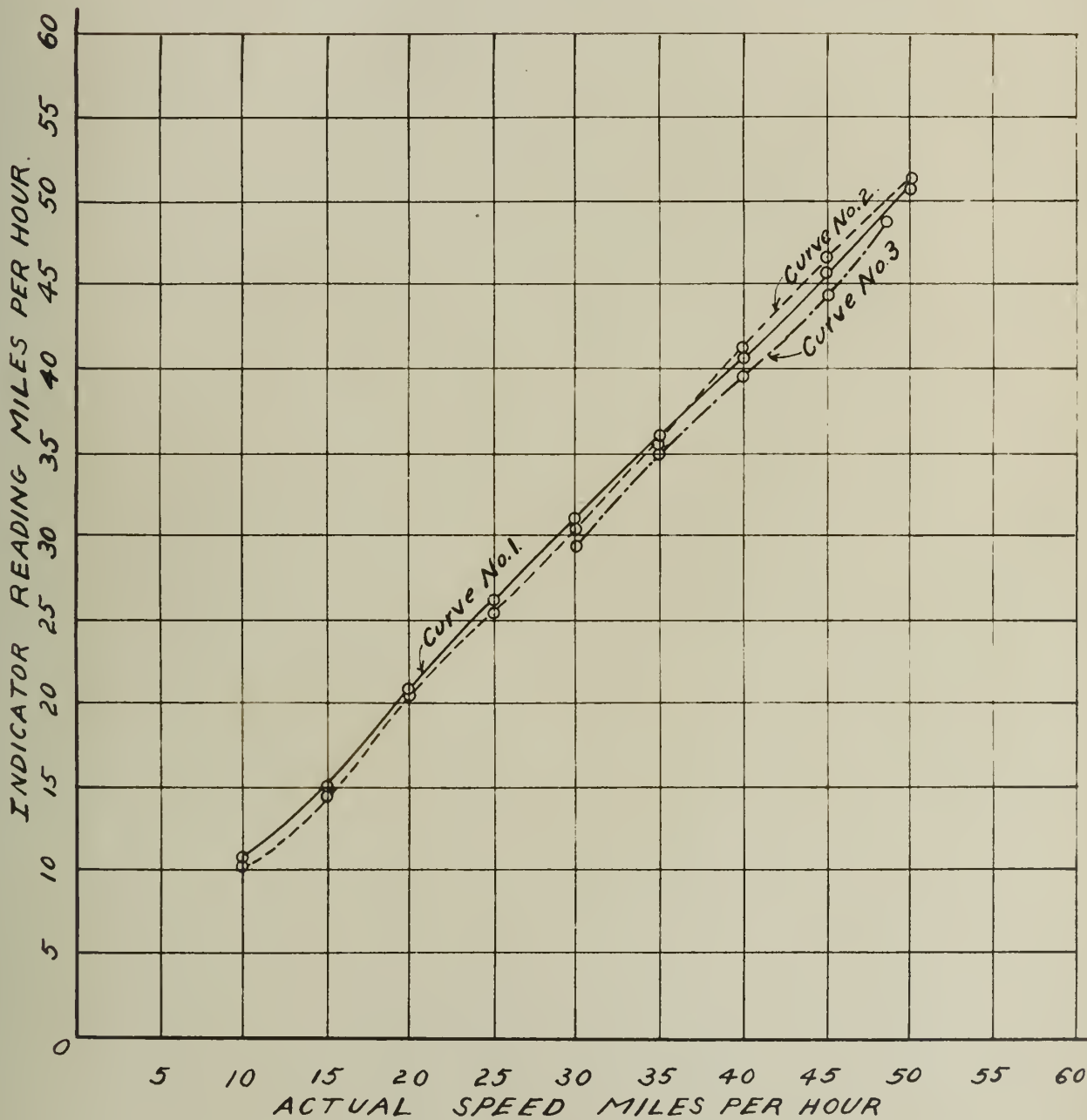
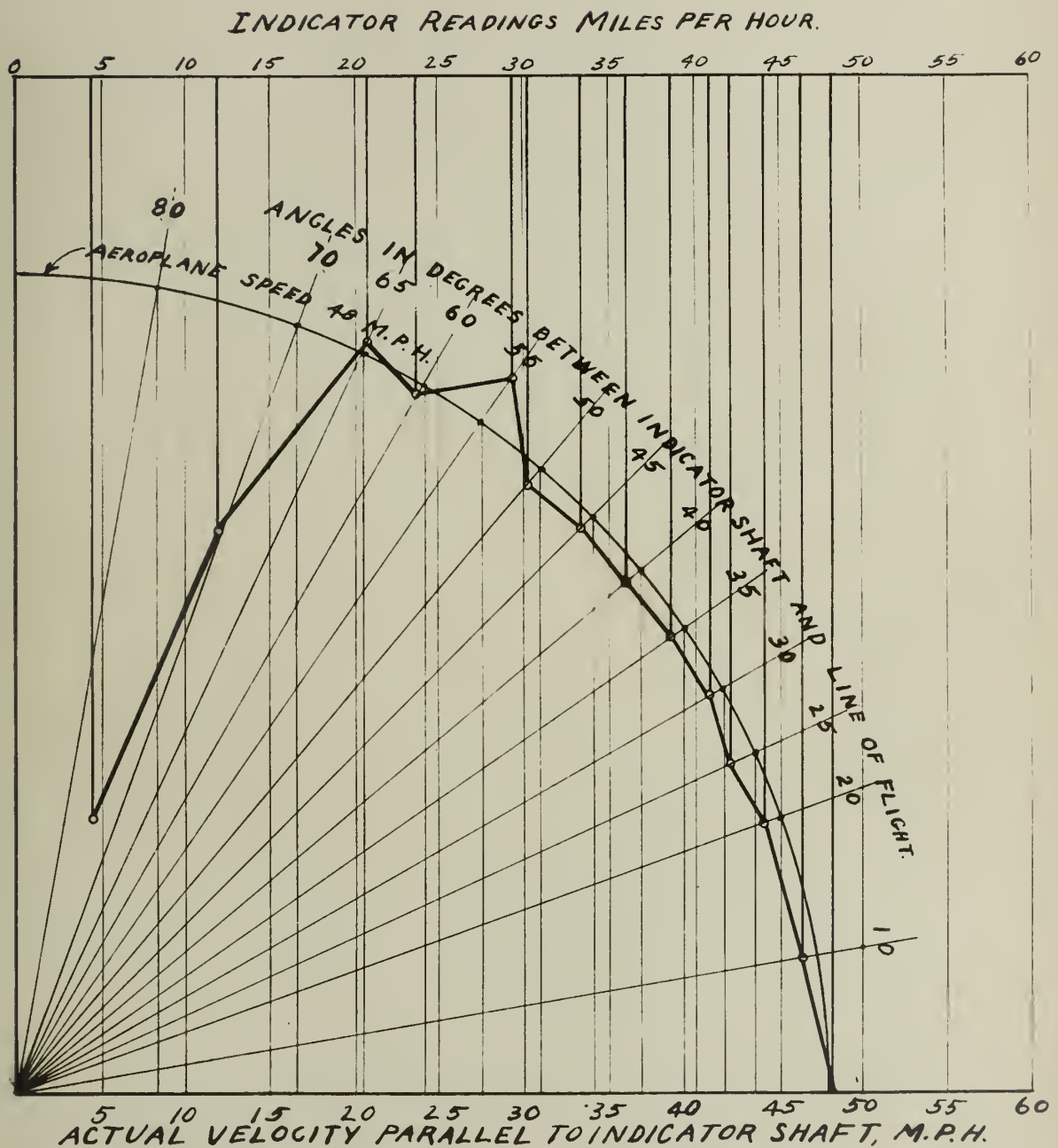


PLATE NO. 2  
AIR SPEED INDICATOR  
CALIBRATION CURVES.





**PLATE NO. 3**  
**AIR SPEED INDICATOR**  
GRAPH SHOWING VARIATION OF READINGS  
WITH VARYING ANGLES BETWEEN  
SHAFT AND LINE OF FLIGHT,  
AEROPLANE SPEED 48 M. P. H.



plotted were the averages of three test runs up the course, and three runs down the course at each speed. The only explanation that can be submitted as to the cause of the variation between curves No. 2 and 3, Plate No. 2, is that the adjacent parts of the motorcycle caused variations in the velocity of the air striking the propeller.

After plotting curve No. 2, Plate No. 2, test runs were made with instrument mounted on the motor-cycle, with the axis of the propeller turned at varying angles with the horizontal, to determine the relation between the recorded speeds, and the angle between the axis of propeller and the air-stream. The results, although erratic, indicated that the readings varied very nearly as the cosine of the angle between the axis of propeller and the air-stream. The indicator was then mounted upon an aeroplane, and test flights made over a straight measured course at a speed of 48 miles per hour; the speed of aeroplane being determined by stop-watch. Although the day was calm, all values plotted are the averages of two runs in each direction, in order to eliminate any possible error due to the wind. Instrument was swung horizontally through the different angles plotted, the shaft being checked for level in each case. The results of these runs are shown by graph on Plate No. 3. The readings at fifty-five degrees were checked several times, and although they show great variations they could not be discarded as inaccurate.

The following conclusions were drawn from the tests:-

That the instrument indicates the air speed with the desired accuracy when propeller shaft is parallel to the air-stream.

That the readings very closely approximate the component of the velocity parallel to the shaft, when the instrument is held with the shaft making an angle of less than forty degrees with the air-stream.

That in case of injury while in use, loss of accuracy, due to friction of the bearings, warping of the propeller, or similar causes, the



instrument will undoubtedly indicate a smaller speed than the actual one, and that such error will tend to promote, instead of decrease, the safety of pilot and machine.

The instrument as built, is small, light, easily mounted, and sufficiently rugged to stand the service demanded.



## CHAPTER V.

## ENGINE IMPROVEMENTS.

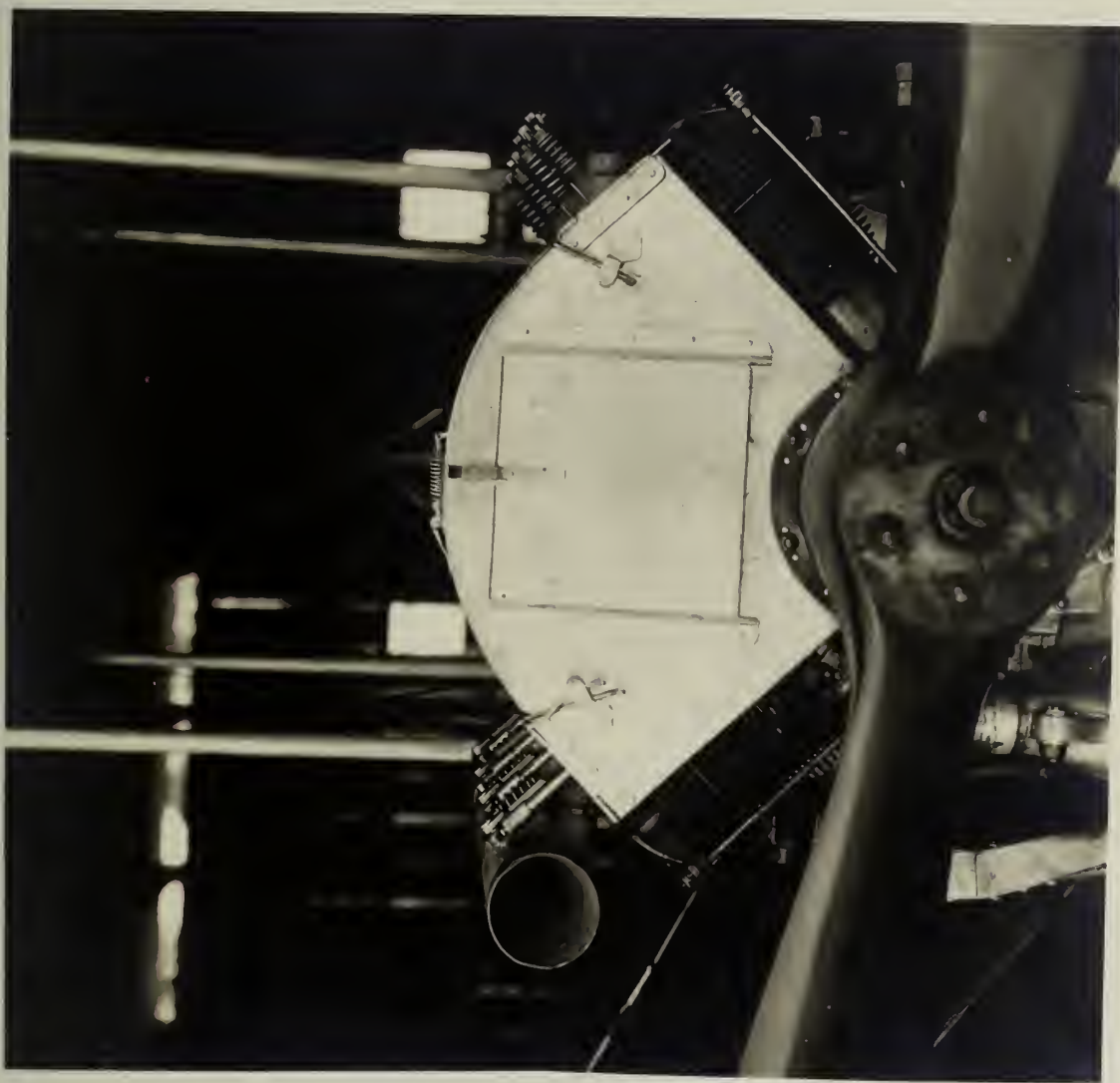
In a previous chapter it has been pointed out why lightness, decreased head-resistance, and excess power are such desirable requisites for military aeroplanes. Every unnecessary pound that is carried cuts down the military suitability and "radius of action". The strength required and the qualities of the construction materials are the limiting factors, as all faults in the engineering design are subject to reduction or elimination. Every square inch of cross-sectional area that must be driven through the air requires the expenditure of power to drive it. The width of the fuselage of the modern tractor aeroplane is usually governed by the dimensions of the motor. The weight and power of the motor are also very important features of the design and the capabilities of the machine.

The following discussion outlines the methods used to modify an engine in an attempt better to meet the requirements of weight, power, and fuselage width, stated above, as well as to improve its reliability and fuel economy.

The 1911 model 70 H. P. Renault aeronautical engine is an air-cooled, eight cylinder, "V" type motor. The cylinders are mounted in two rows of four each, the axes of opposite cylinders making an angle of ninety degrees with each other. The bore is 96 mm., the stroke 120 mm., and the connecting-rods are 240 mm. long. The crankshaft has four throws, the two middle crank-pins being in the same line, and offset 180 degrees from the two end crank-pins. The carbureter is of the automatic type, the auxiliary air-valve being arranged with a vacuum dashpot device to compensate for changes of the density of the air, due to altitude or barometric changes. The primary air is heated by passing the exhaust from four cylinders through a jacket around the air intake-pipes. This carbureter is not adapted for an equal distribution of the mixture to all cylinders, as the location and



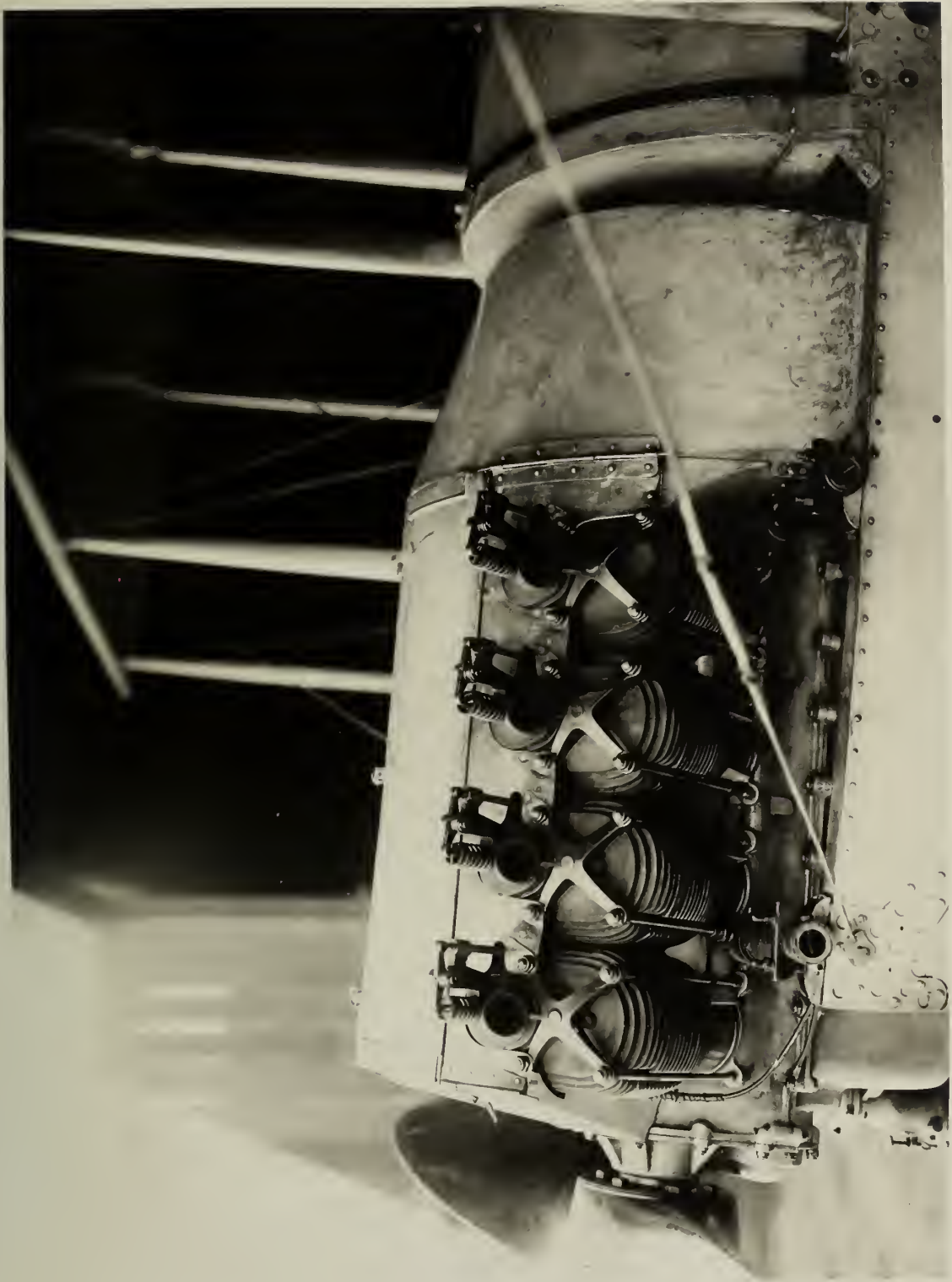
*( To follow page No. 22 )*



*PLATE NO. 4  
FRONT VIEW RENAULT MOTOR  
SHOWING ORIGINAL HOUSING*



*( To follow page No.22)*



*PLATE NO.5  
SIDE VIEW RENAULT MOTOR  
SHOWING ORIGINAL HOUSING*



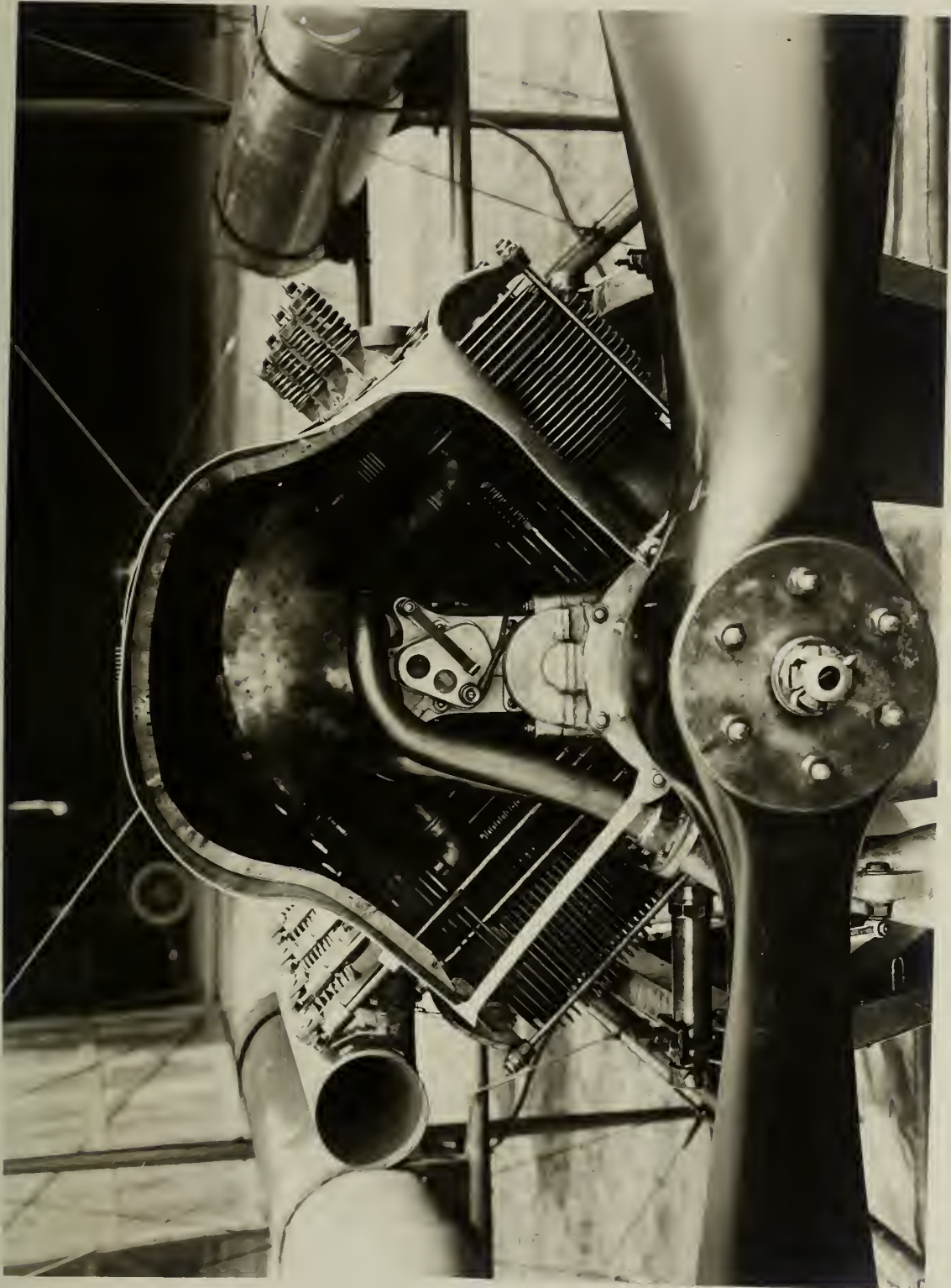
arrangement of the carbureter necessitates that the manifold be divided into two lines, each line serving the four cylinders on that side of the engine, through branches taken off in succession from front to rear. The intake manifolds, as can be seen on Plate No. 6, are located within the "V" formed by the cylinders. The inside diameter of the intake manifolds and branches is 30 mm. There is no baffling, nor other provision made to insure equal distribution of the mixture to the different cylinders. The ignition is furnished by a Bosch high tension magneto, the H-L-8 model being used. This magneto is mounted upon a boss cast on top of the upper crank-case, at the propeller end of same, in the center of the "V". The magneto-gear meshes with a gear upon the camshaft, no flexible coupling nor other vibration-eliminating device being used.

The cooling system of this motor consists of a steel-plate centrifugal fan, 51 cm. in diameter, keyed upon an extension of the crank-shaft at the end opposite the propeller. Fan rotates at 1800 R. P. M. It is inclosed in an aluminum involute housing, discharging into the "V" through an opening of approximately 725 sq. cm. The top of the "V" is closed by an aluminum hood which is fastened to the fan housing, the cylinders, and to an aluminum end-plate at the propeller end of the motor. The working portions of the cylinders have cooling "fins", forming rings about 2cm. wide. The spaces between the necks of the cylinders are closed by baffle-plates to prevent air leakage. The air blast from the fan is thus forced out of the inclosed "V", passing between adjacent cylinders through the small spaces between the cooling fins.

This motor was originally designed for the "pusher" type of aeroplane, and the design was made several years ago when the speed of aeroplanes was comparatively low, less than 60 miles per hour. The power required to drive the large fan-housing through the air at that speed was relatively



*(To follow page No. 23)*



*PLATE NO. 6  
FRONT VIEW RENAULT MOTOR  
SHOWING IMPROVED HOUSING*



( To follow page No. 23 )



PLATE NO. 7  
SIDE VIEW RENAULT MOTOR  
SHOWING IMPROVED HOUSING



small. The modern type of military aeroplane has the propeller in front, and has the body, or fuselage, covered with cloth, and shaped so as to offer as small resistance to the air as possible. To reduce the head resistance the fuselages are now built "stream-lined", that is, cigar, or torpedo-shaped, the cross-section of same being made as small as possible, and the motor and operators being almost entirely inclosed.

The U. S. Army had several Renault motors on hand, and in order to adapt them for use in the later type machine, with narrow fuselages, it was necessary to change the fan housing. It was also desired to lighten these motors if possible.

The problem presented was:-

To reduce the over-all fuselage width of the motor.

To reduce the weight.

To secure more even distribution of the mixture.

To provide a flexible coupling, or other means of eliminating the vibration in the magneto, due to the pounding of the driving gears.

To change the intake manifolds so that an American carbureter could be used.

To utilize at the propeller the power consumed by the fan.

The first consideration was the most important, and three years ago an attempt was made to operate these motors without the fan, housing, or hood; the cylinders being left exposed with the idea that the blast of air due to the speed of the machine would furnish sufficient cooling. This attempt proved a complete failure, the motor becoming so hot that pre-ignition occurred. After this trial nothing more was done until March 1914, when the author suggested that a sufficient circulation of air for proper cooling could be obtained if a cowl-shaped hood was substituted for the fan. A hood of this type was constructed and installed, but on account of the move-



ment of the 1st. Aero Company from San Diego, California, to Galveston, Texas, in April, 1914, no tests were made until August of that year.

Before testing the motor without the fan, calculations were made to determine whether or not the fly-wheel effect due to the fan was necessary to insure proper smoothness of operation. The fan was dismounted, weighed, and measured, then suspended from a point on the periphery and swung as a pendulum, and the period of vibration timed. The radii of gyration about the point of suspension and about the axis of the fan were calculated. It was found that such a great proportion of the weight of the fan was in the cast-iron hub, that the fly-wheel effect was so small it was negligible. The overlapping of power-strokes, due to the fact that there was an explosion every ninety degrees of crank-shaft travel, also indicated that the fly-wheel effect of the fan was unnecessary.

This motor has a fixed spark, the advance being approximately thirty degrees of crank-pin or 12 mm. of piston travel. The exhaust valve opens fifty degrees before the piston reaches the lower dead-center, the final pressure being fairly high. The effective power-stroke consisted of 130 degrees of crank-pin travel, the final pressure was fairly high, and an explosion occurred every ninety degrees of shaft rotation, so the forty degrees that the power-strokes over-lapped insured a very slight variation in torque, at a speed of 1800 R. P. M. This belief was strengthened by consideration of the fact that the forged steel pistons, connecting-rods, and other reciprocating parts, were very light in comparison with the heavy crank-shaft.

It having been determined that no flywheel would be needed, the size of the cowl opening and the shape of the hood were investigated. As none of the manufacturer's data, nor facilities for testing the discharge of the fan and the rise in temperature of the cooling-air, were available, it was assumed that the results of tests of a similiar fan made by an American manufacturer



would be sufficiently accurate.

These results showed that with a circumferential velocity of 150 feet per second a discharge of 4000 cubic feet of air per minute might be expected. The tests also showed that such a fan would require 4.8 H. P. to drive it. The speed of the Burgess Type H aeroplane, in which these motors were used, was sixty miles per hour. At a speed of a mile a minute an effective opening of one square foot would supply a volume of air in excess of that furnished by the blower. As the disturbing effect of the propeller, mounted a short distance in front of the opening, could not be calculated, the cowl was built with an opening of approximately 1.4 sq. ft. This increase was also believed necessary on account of the "blanketing" effect of the magneto and manifolds, which it was desired to leave as originally installed until after the first tests. As the propeller revolved in a clockwise direction (when viewed from in front of the aeroplane), the hood on the left side of the front of the engine was shaped to collect the air being driven in the direction of rotation of the propeller, the other side being left open as shown by Plate No.

The engine was installed in Signal Corps Aeroplane No. 26 (Burgess Type H tractor), and after a preliminary "warming up" a fifteen minute flight was made. The R. P. M. of the motor in the air was found to be 1960. The normal R. P. M. of this motor under similar conditions in the same machine was 1840. After alighting the motor was closely examined with the cylinders removed, and everything appeared normal. No signs of overheating, or of failure of lubrication, could be detected. It was impracticable to obtain temperature readings of the cylinders while in flight, and readings taken after landing would have no comparative value, as it was impossible to repeat exactly the same conditions of throttling and the speed of volplaning for several test flights.

After re-assembly the machine was flown several times for periods of



from twenty minutes to one hour, and, except for the increased R. P. M. and speed of the aeroplane, no difference in the operation of the motor under the new conditions, as compared with the old, could be detected. After every flight the relative temperatures of the different cylinders were noted, and it was found that the cylinders were not equally cooled, but that the pair at the rear end of the motor was much cooler than any of the others, while the second pair from the front was the hottest, the first and third pairs were about the same temperature. This result had been foreseen as it was expected that the magneto and intake manifolds would stream-line the air past the openings between the center pairs of cylinders, and that the greatest amount of air would be forced out around the rear cylinders, so some effort had been made to partly block the openings around these cylinders with baffle-plates.

The motor having been flown in a series of short flights for a total of more than five hours, without any signs of pre-ignition, failure of lubrication, cylinder scoring, warping or pitting cylinders, pistons, or valves, it was considered that the cowl-shaped hood furnished sufficient air for properly cooling the cylinders, although the air was not equally distributed to all cylinders, nor economically utilized. Before proceeding with the further development of the hood, it was desired to test the cooling of the motor under the conditions liable to be encountered in service. After discussion with experienced aviators the following requirements were selected to govern the test; these requirements being based upon the idea of the worst conditions that would be likely to be met with in military aviation in the vicinity of Vera Cruz, Mexico.

"The day to be clear and calm, and as hot as is usual at San Diego, California, during August and September. In order to obtain the full effect of the heat of the atmosphere near the earth the altitude for the entire flight



should be not more than 1000 feet above sea level. The flight should be of about three hours duration and the throttle wide open from the start until after the machine lands. The descent ought to be made very gradually, and, except in case of emergency, at a rate of not more than 100 feet per minute. The machine to start with at least four hours' fuel and oil, and to carry pilot and passenger. Weight of pilot and passenger to be at least 300 pounds. Engine to be dis-assembled and inspected immediately after test; cylinders and pistons to be calipered in order to detect any warping. All valves to be inspected for pitting and warping, and tested for tightness. Flight to start between eight and nine A. M., in order to finish before noon, the time that the ocean breeze usually begins."

Motor was dis-assembled, cleaned, and inspected; all cylinders and pistons tested for round with micrometer-gauges, reading to .0005 inch. Conditions of valves noted, and tested for tightness with liquid gasoline. As the exhaust valve-springs seat upon the top of the cylinders and there was a faint possibility of their being affected by any undue heating of the cylinder-heads, the springs were calibrated. From the records of a great many hours running, the following quantities were taken as the hourly consumption of gasoline and oil, for this motor, at speeds varying between 1760 and 1840 R. P. M.:-

Gasoline (62 degrees, Beaumé), 8.3 gals. per hour.  
Oil (Monogram, Extra Heavy), .7 gals. per hour.

Motor was re-assembled, and 2.8 gals. of oil put into the sump. Although the gasoline required for four hours run amounted to only 33.2 gals., in order to increase the load upon the motor as much as possible, the tanks were filled with 46.7 gals. The combined weight of pilot and passenger was 315 pounds.

After waiting for several days for the desired weather conditions the flight was made on August 11, 1914. The engine was run on the ground immedi-



ately before flight, until thoroughly warmed up. R. P. M. on the ground with the engine hot was 1872. Flight started at 8:16 A. M. Climbed at rate of 320 feet per minute until altitude of 860 feet was reached. Flew level, at this altitude until 9:08 A. M., when it became necessary to climb to 1380 feet to get out of the way of training machines. Flew level at 1380 feet from 9:12 until 9:21, coming down gradually to 700 feet. This level was reached at 9:30 A. M. Remained between 700 and 800 feet from 9:30 until 10:49, when descent was begun. Descended at uniform rate, landing at 11:14 A. M. Closed throttle about twenty seconds after landing. The R. P. M. was taken at ten minute intervals by speed counter and stop-watch. Altitudes by recording barographs. The tabulated results are given below:-

S. C. Aeroplane, No. 26.  
 (Burgess Tractor, H.)  
 Motor, Renault, 8 cyl., 70 H. P., fanless. (Experimental).  
 Pilot, Dodd. Passenger, Morrow.  
 San Diego, Cal., Aug. 11, 1914.

Time, A. M.	Temperature,	Altitude of	R. P. M.
8:11	84.0	On ground.	1872
8:18	84.0	Not taken.	1940
8:28	84.2	860 ft.	1965
8:38	84.2	860 "	1968
8:48	84.2	860 "	1975
8:58	84.4	870 "	1970
9:08	84.6	970 "	1960
9:18	84.8	1380 "	1980
9:28	85.0	720 "	1975
9:38	84.8	700 "	1965
9:48	85.4	720 "	1960
9:58	85.4	700 "	1965
10:08	85.6	700 "	1965
10:18	85.8	700 "	1955
10:28	85.8	700 "	1955
10:38	85.8	700 "	1955
10:48	85.8	700 "	1955
10:58	85.8	500 "	1965
11:08	85.8	220 "	1970
11:11	85.8	50 "	1970

Immediately after the engine was stopped an attempt was made to obtain the temperatures of the walls of the cylinders inside the "V", but the thermometers had not been warmed to near the engine temperature and the metal



cooled so quickly that no readings could be obtained. Judging by the sense of touch, the two cylinders at the rear were much cooler than the others, which seemed to be about the same temperature as is customary when the fan is used. After the engine cooled it was dis-assembled and examined. No sign of overheating was found, the valves being tight and true. Pistons and cylinders were carefully gauged, and no variation from the previous measurements found. Lubrication of pistons and cylinder walls had been excellent. There was no sign of scoring or undue wear. The oil and gasoline tanks were measured to obtain the consumption. Total time that engine was run at full speed, on ground and in air, was three hours and three minutes, and total time in air two hours and fifty-eight minutes. Oil used per hour, .73 gallons. Gasoline per hour 8.6 gallons.

The original cooling system was re-placed and tests of speed and climbing ability made. Speed, average of several runs, 59.83 M. P. H. Climb, full load, 240 feet per minute, for 1500 feet.

Without making any other changes, except that fanless cooling system was used, speed, 62.3 M. P. H., climb, 308 feet per minute, for 1500 feet.

It was impossible to accurately decide whether or not the increase in power at the propeller was due entirely to the removal of the power-consuming fan, or whether it was due to the difference in the working temperatures. As long as the temperature remained low enough to permit successful lubrication and prevent pre-ignition, and warping of the cylinders or valves, the cause was considered as of no importance. The results obtained are sufficient to cause the new cooling-system to be considered as an improvement in power. The decrease in weight is also considered important, it amounting to seven per cent of the total weight. The fuel and oil consumption per hour remain about the same, but with a decrease in the fuel and oil per mile. This item is so small as to be regarded as of little importance. The in-



crease in the climbing rate and the decrease in the permissible width of fuselage are regarded as very great improvements.

In order that the full value of the new method of cooling be obtained, the manifolds and carbureter, as well as the location of the magneto, must be changed. This is being done, and if successful, the size of the hood can be decreased, thus decreasing the head-resistance of the machine without interfering with the proper cooling.



## CHAPTER VI.

## WIRELESS TELEGRAPHY.

The knowledge of the enemy's strength, location, movement, and disposition. etc., obtained by the air-scout, is of absolutely no value as a factor in the fight unless it can be conveyed to the commander of the troops, so that he will be able to handle his fighting units in such a way as to derive the benefit of the information. If the air-scout has flown over the enemy's advanced lines, and while in their rear discovers items of importance, it is very desirable that the information be transmitted to his own troops at once as a chance shot may soon bring him to earth, captive or slain. There may be other important areas to be searched immediately, and the time required to return to within his own lines with the first obtained information can not be spared as the enemy may also be on the alert and the attempt to return offer scant hopes of success. The important thing is to send back the information, and to send it at once. It may mean the life or death of thousands of his country-men, if the knowledge of the situation that he has seen can be placed at the disposal of his commanding officer. Some means of rapid communication is necessary, and radio-telegraphy and radio-telephony are the only known devices that can be utilized to communicate from an air-craft, across several miles of territory occupied by hostile forces.

It may also be desired to direct long-range gun-fire at targets that are invisible from the batteries, but which can easily be seen from above.

For such communications radio offers an almost ideal solution, especially, if a cipher-code unknown to the enemy is used.

The first experiments with the wireless telegraph from an aeroplane were made in 1910, and in this, as in the art of aviation, America was the pioneer. The first attempts were not entirely successful, the aeroplanes and instruments being poorly adapted for the work. In connection with maneuvers held



in 1911, experiments in reporting the movements of the "enemy" were made, but due to the defective apparatus, there was little certainty that the messages sent would be intelligible at the receiving stations.

The ordinary radio apparatus has a "ground" connection to the earth or water, and can have a large insulating gap between the "ground" and the aerial antennae. The aeroplane is a self-contained body, and while in flight is separated so far from the earth that a "ground" wire is impracticable. With the increase in the knowledge of radio actions, the necessity of an actual metallic connection with the earth has been dis-proven. The radio impulses will be set up in the ether if two electrodes are provided to propagate them.

The ordinary military aeroplane has more than 1000 feet of wires in its structure, and these wires are metallically, and therefore, electrically, connected. By connecting the ground terminal of the apparatus to the structural wires, a "ground" or counterpoise is obtained. An "aerial" can be stretched between portions of the framework, but the better and simpler method, is to suspend a weighted wire from the lower part of the aeroplane. This wire must be so arranged that it will not interfere with the movements of the machine while same is on the ground. In order to permit the necessary movements on the ground the aerial must be held inclosed within the body of the machine until after the aeroplane has risen from the earth. Some means must be provided for lowering the "aerial" while in flight, and also for retracting or else severing the suspended wires before the aeroplane alights. A source of the electrical energy, the sending-key, spark-gap, tuning-coil, condenser, etc., must also be provided.

The aerial offers few difficulties, and these can be easily over-come. An alternating current generator of sufficient power and high frequency for sending messages a distance of sixty miles, can be constructed sufficiently light in weight without much trouble, but the problem of driving same offers



quite a number of mechanical difficulties. No difficulties have been encountered in mounting and using the other apparatus; any of the standard marine-type equipment being suitable for aeroplane work.

A special generator was designed and built for the army use which was very light, compact and self-contained. The unit consisted of two distinct windings upon separate cores, mounted on the same armature shaft, and rotated between poles that were parts of two separate magnetic circuits. This generator comprised within itself two separate generators, one of which was a direct-current exciter that energized the revolving field of the alternating-current dynamo. The normal speed was 5000 R. P. M., A. C. voltage of 125, 500 cycles, and 250 volt-amperes capacity. The generator was of the ordinary cylindrical, multiple-pole type, both the fields and the armature-cores being of laminated iron, the iron yoke or frame being designed for the magnetic requirements only. To provide sufficient strength, and to furnish supports for the end-bearing-brackets, an aluminum frame was placed around the iron yokes; this frame being a barrel-shaped casting. The total weight of the 250 volt-ampere generator was 24 pounds; its length, over all, 11 inches; greatest diameter, 5 inches. As will be seen from the above dimensions it formed an extremely light and compact unit.

The experience in 1910 and 1911, with friction drive from the fly-wheel of the aeroplane engine, had proved that this method of drive was not satisfactory. On account of the vibration of the engine and the generator base, the friction wheels had to be kept under a very great pressure, or else slippage occurred. If pressure sufficient to prevent slippage was exerted, the wear upon the generator bearings was excessive; if slippage occurred, the frequency and voltage were subject to sudden changes, with corresponding variations in the radio impulses, thus making it extremely difficult to read the messages. An attempt was made to use a chain drive, and a well known type of



silent chain was manufactured in 1914 for this generator; the driving sprocket to be mounted upon the rear end of the crankshaft of the aeroplane engine. The chain manufacturer would not guarantee the chain against breakage at the high speed that it was necessary to drive the generator and exhaustive tests of this type chain were made at the Bureau of Standards Laboratory, Washington, D. C. The laboratory tests showed that the chain would stand up under the work and the equipment was sent to the Aviation School for practical tests and use upon the Army aeroplanes. When the transmission was tested at Washington strong guards were placed to prevent danger in case of failure of chain sprockets. It was impracticable to install such guards in the aeroplanes, and the damage that might result in case of failure at a high altitude would be so great that it was considered too dangerous to use this method of driving. It was necessary to mount the generator in the fuselage near the engine, and if the chain failed the loose ends might possibly cut the longerons and cause a fatal wreck. It would be extremely difficult to preserve the parallel alignment of the shafts and the distance between centers unless the generator was rigidly connected to the engine. These reasons made it desirable to use a gear drive, and involute spur gears were designed and cut for this work. The teeth were cut with the standard pitch angle of  $14\frac{1}{2}$  degrees and with a factor of safety of 20. As the crankshaft speed was 1840 R. P. M. and the generator speed desired was 5000 R. P. M. the gear ratio was 100 to 37. This tooth ratio also insured evenness of wear. An aluminum bracket was made to form a support for the generator. This bracket was bolted firmly to the rear of the crank-case of the engine, the distance between shafts being very accurately adjusted. The generator would not be in constant use, so to save wear upon the bearings it was deemed advisable to mount the driven gear as an idler with a friction clutch that could be thrown in whenever the current was desired. The driven gear was keyed upon a short jack-shaft that turned in bronze bear-



ings. After a few hours operation the bearings had become so worn that the gears meshed improperly and the armature had an excessive vibration whenever the clutch was thrown in. Bearings of a different grade of bronze and of babbitt were tried but it was found that a plain bearing would not stand up under the speed and vibration, so the jack-shaft was then mounted in ball-bearings. The outer races were mounted in steel cups ground to a close running fit and with an allowance for an axial "creep" of .03 inch. The friction clutch used was of the well known expanding radial type with hardened and ground steel faces. The clutch was actuated by the operator's foot, pressure upon the pedal permitting the clutch-spring to expand the jaws. A counter-spring released the clutch when the pressure was removed. This mounting proved entirely satisfactory although the gears were a trifle noisy.

A field rheostat for the direct-current generator and a step-up transformer with adjustable secondary windings were mounted near the operator's seat. A key, condenser, tuning-coil, and rotary quenched-spark-gap were mounted upon a small table in front of the operator. Clips for holding message blanks and paper also were mounted upon the table and protected from the air-blast by an aluminum wind shield. A small wire-reel was fastened to the floor of the fuselage, the aerial (consisting of 19 strands of phosphur-bronze wire 400 feet long, with a two pound weight attached to the lower end), was coiled upon this reel. The reel was operated by a small crank and was provided with a pawl and ratchet stop. A pair of wire-cutters upon an insulated mounting were placed so that their jaws would embrace the suspended wire. A lanyard with insulated handle was attached to the wire-cutters so that the hanging wire could be cut if there was insufficient time for reeling-in before the machine would be near the ground. Two extra spools of aerial wire made up complete with weights ready for placing upon the reel-spindle were carried in the machine.



The estimated day radius of this equipment was 60 miles under normal conditions, and the tests that were made indicated that the messages would be clearly received by the standard army pack-set at a much greater distance. The complete aeroplane equipment weighed only 82 pounds, including generator-base, clutch, and gears. This set formed a sending station only, and although some attempts have been made to use receiving apparatus, the vibration of the aeroplane and the noise of the engine-exhaust have been obstacles that prevented success. The air-scout will be able to send his message but will have no way of telling whether or not it has been received, nor is he able to receive new instructions from the base. As soon as the receiving station problems are solved the radio-telegraph will become an extremely valuable auxiliary for military aviation work. At the present time the ability to communicate with the ground from the aeroplane is so desirable that it is beyond all question worth while adding the weight of the sending set to the load that is carried.

Vibration and noise have prevented the use of the radio-telephone for either sending or receiving, but if these obstacles can be overcome the ideal method of reconnaissance reporting will then be available.



## CHAPTER VII.

## AGGRESSIVE WEAPONS.

Before the first power-driven aeroplane flight was made there had been many inventions for conducting offensive warfare from dirigible balloons and kites, and a great many devices had been invented for use on some strange and as yet unknown craft described by the ambiguous term "airship". These devices comprised catapults, air-guns, spring-guns, small cannon and machine-guns, and several weapons that can be classified under no other term than "freaks". There have been many patents issued for projectiles for aggressive action from air-craft, the greater portions of the patents covering details of the construction of the missiles, their contents, or their action after striking the target. There have been many attempts to drop projectiles from balloons and aeroplanes upon a small target, but in the greater majority of cases the placing of the projectile depended simply upon the aviator's judgment of speed, distance and height, and the results were so erratic that the military value of the aeroplane as an aggressive weapon was regarded as unimportant.

In order to develop the practice of bomb-dropping a contest was held in France for the Michelin Prize for the most accurate work. This prize was won by Mr. Riley E. Scott, a resigned officer from the United States Army.

Mr. Scott's device consisted of a telescopic sight mounted upon a level table (the table being suspended upon gimbals), an inverted solar quadrant, a stop-watch, an aneroid barometer, and "range tables" for the different altitudes, and his method is based upon the following assumptions:-

The time required for the projectile to fall from the aeroplane to the earth varies as function of the altitude, shape and density of the projectile.

The horizontal travel of the projectile due to the velocity imparted by the moving aeroplane varies as functions of the time of flight, shape and density of the missile. The effect of winds at the height of the aeroplane are



very important, but, that for ordinary working altitudes the winds between the aeroplane and target have no appreciable effect upon the projectile. The variations in the retarding effect of the atmosphere due to barometric changes may be neglected. The only variables that require consideration are:-

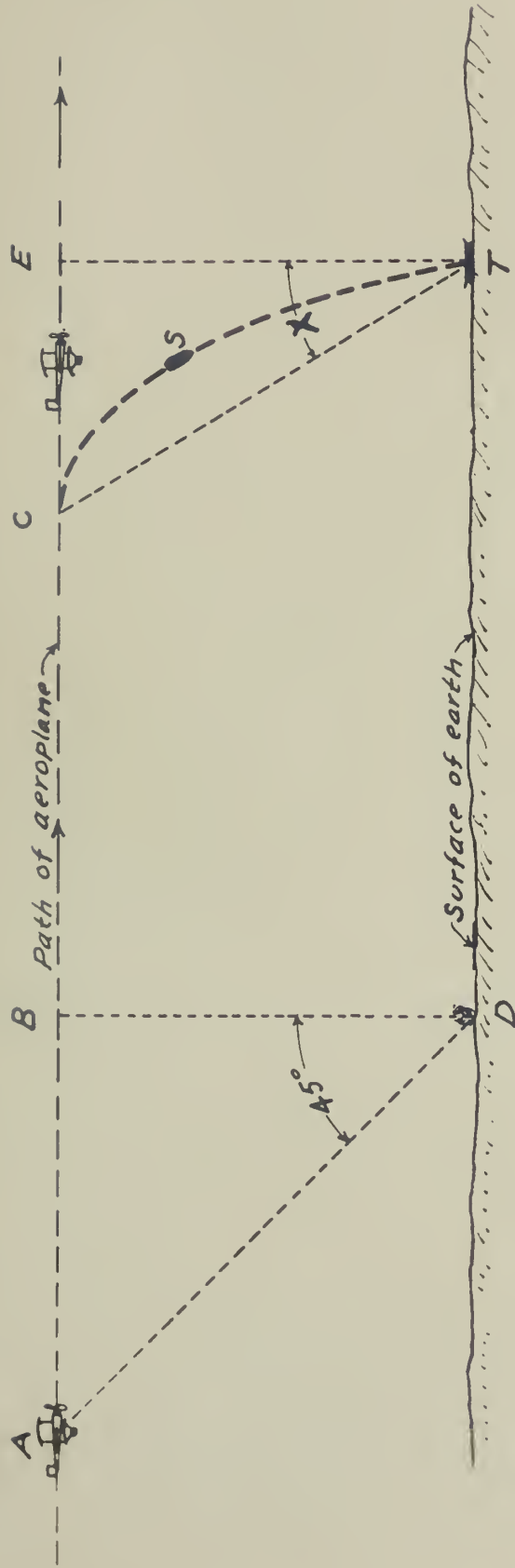
1. Weight and shape of projectile.
2. Height of the aeroplane above target.
3. Horizontal velocity of the aeroplane with respect to the target.

The variable 1 becomes a constant for any one type of shell and may be expressed as the "ballistic co-efficient" for that particular projectile.

The variable 2 changes with each change of altitude. By means of the aneroid barometer the height of the aeroplane above its starting point can be determined at a glance, and with properly calibrated instruments the instrumental error will be negligible. If the target is the same height above sea-level as the starting point, the aneroid barometer can be set at zero on the ground, and the height of the aeroplane above target read directly from the instrument scale. If the altitude of the target above sea-level is different from the altitude of the point where the flight started it will be necessary to correct the aneroid reading so as to show the height of the machine above the target, and not the height of the machine above the starting point. If reliable contour maps are available upon which the target can be located the difference in altitude of the starting point and the target can be corrected for by shifting the index on the barometer, so that the zero reading will correspond to the altitude of the target above sea-level. This correction would be made as soon as the location of the target was determined, before leaving the ground if the site of the target was known, or if not, as soon as the target was located from the aeroplane.

If contour maps are not available or if the target is discovered after the flight is begun, the pilot, if experienced, will be able to estimate very





### PLATE NO. 8

#### METHOD OF OPERATION OF BOMB-DROPPING-DEVICE

$D$  = Any well-defined point that aeroplane will pass over as it approaches the target.  
 $A$  = Point where watch is started.  $\overline{AD}$  = The line of vision through sight.  
 $\overline{BD}$  = Altitude, as read from aneroid barometer.  $B$  = Point where watch is stopped.  
 The number of seconds required to fly from  $A$  to  $B$  is read on watch, and the sight is set to the corresponding curve on instrument. The axis of sight will then make the angle  $X$  with the vertical. When aeroplane reaches  $C$ , the target,  $T$ , will appear upon the cross-wires, and projectile is dropped. The projectile follows the curved trajectory,  $\overline{CST}$ .



closely the difference in the height of site of target and the height of site of some known point within view. Pilots flying across new country develop the faculty of sub-consciously noting the heights of the terrain over which they fly, and as a general rule will be able to judge very accurately the altitude of a point several miles from their starting point.

The variable 3 is the one that offers the greatest difficulty as this variable depends upon the wind, engine, load, and the method of flying. This variable is constantly changing, and the corrections for same must be made immediately before the projectile is dropped. The horizontal velocity of the aeroplane with respect to the target is determined as follows:-

Some well-defined point on the earth is selected that lies between the target and the aeroplane (a tree, house, cross-roads, or other easily distinguished mark being used), and the telescopic sight is set at an angle of 45 degrees with the vertical. The "gunner" observes through the sight until the object appears upon the transverse cross-wires of the instrument. He then starts the watch and sets the telescope vertical, again observing the object and stopping the watch when the mark appears upon the transverse cross-wires the second time. The watch indicates the time required by the aeroplane to travel through a horizontal distance that is equal to the vertical distance from the aeroplane to the ground. (See Plate No. 8 ). The vertical distance having been read from the aneroid barometer and the time required to travel an equal distance horizontally having been read from the watch, the horizontal velocity of the aeroplane with respect to the earth can be obtained from previously calculated tables.

The height of the aeroplane being known and the variable 1 having been determined for each type of projectile, the "time of flight", that is, the time required for the projectile to fall from the aeroplane to the ground, can be calculated.



At the instant that the projectile is released it has a horizontal velocity with respect to the earth that is equal to the horizontal velocity of the aeroplane with respect to the earth, and the time of flight being known, the horizontal distance that will be travelled by the projectile during its fall can be calculated.

In order to determine the proper moment to release the projectile the telescopic sight is set at an angle whose tangent is equal to the distance that the shell will travel horizontally divided by the altitude of the aeroplane above target. As the aeroplane approaches directly above the target the projectile is released the instant that the target appears upon the transverse cross-wires of the sight. (See Plate No. 8 ).

The Scott device requires an aviator to pilot the aeroplane and a "gunner" to operate the fire-control device and drop the projectile.

Tables were compiled to show the relation between the number of seconds that the aeroplane required to travel the distance  $\overline{AB}$ , (Plate No. 8 ), and the angle of sight,  $X$ , for the different altitudes at which it was desired to fire. These tables applied to one type of projectile only and were computed in the following manner:-

$h$  = height in feet.

$g$  = acceleration due to gravity.

$t$  = time of fall in seconds,  $= \sqrt{\frac{2h}{g}} = \frac{\sqrt{h}}{4.01}$ .

This equation does not apply to the conditions to be met with in practice, for it does not take into account the retarding effect of the atmosphere. This retarding effect varies as a function of the velocity, and also with the shape and density of the falling body. As the result of a great many tests, empirical equations for different type projectiles have been determined that are used to correct the value of  $t$  as given above. As these equations are unnecessary in order to explain the principles involved, and as it would be in-



discreet to divulge them in a treatise of this type, they will be omitted.

The effect of the variations of the value of  $g$  with latitude and height above sea-level have been found to be negligible in this work.

The following indicates the method of calculating the "range tables" for a height of 2500 feet and for aeroplane speeds (with respect to the earth), of from 30 to 60 miles per hour:-

$$t = \frac{\sqrt{h}}{4.01},$$

$$h = 2500,$$

$$\sqrt{h} = 50, \text{ then}$$

$t = 12.45$  seconds, = time of flight of projectile, the resistance of the air being neglected.

Time in seconds required for aero- plane to travel from <i>A</i> to <i>B</i> , Plate No. 8, $h = 2500$ ft.	Velocity of aero- plane and initial velocity of pro- jectile, ft. per second.	Horizontal travel of projectile during time of fall.	Tan of angle $X$ , Plate No. 8 .	Angle $X$ , Plate No. 8 , the angle of sight.
20	125	1560	.625	32 0
22	114	1420	.568	29 30
24	104	1300	.520	27 30
26	96	1200	.480	25 40
28	89	1100	.444	24 0
30	83	1030	.412	22 20
32	78	970	.388	21 15
34	73.5	910	.364	20 0
36	69.5	865	.346	19 10
38	66	820	.328	18 15
40	62.5	780	.312	17 20

Tables were computed for every 300 feet difference in heights between 1500 and 4500 feet, as it is believed that bomb-dropping will be done between these limits. After compiling and checking, columns two, three and four were omitted and tables condensed to include only column one, the time in seconds as read from the stop-watch, and column five, the angle of sight. In the Scott method these tables were typewritten and pasted upon small brass plates. It was necessary for the "gunner" to have eleven separate tables in order to be able to determine the setting of the sight for each 300 feet variation in alti-



tude above the target. It was also necessary that interpolations be made for differences less than 300 feet. The handling of the tables and the necessity of interpolation were found to be grave defects. Another pronounced defect was that the "gunner" had no control of the lateral deviation of the aeroplane from a path that would cause it to pass directly over the target. The pilot was responsible for the lateral accuracy and a plumb-bob arrangement, consisting of a weighted wire ring suspended with its plane parallel to the longitudinal axis of the aeroplane, was provided to furnish a means of correcting the direction of the travel of the aeroplane, so that its path would lie in a vertical plane passing through the target.

The author did some piloting for Mr. Scott, and found that at heights above 1800 feet the ring was not sufficiently accurate, especially if the air was rough. Another defect of the two-man system was that the pilot had no way of telling just when the bomb was to be released, and if the air conditions were so bad that the aeroplane could not continuously be held in line with the target there was no way of judging the exact moment to bring the machine into line. The results of several tests in March and April of 1914, showed that the greater number of the "misses" were "deflection errors" due to the pilot driving to one side or other of the target and not directly over it. Before a method of correcting this defect had been found the tests were stopped on account of the movement of the 1st. Aero Company to Galveston, Texas, for prospective service in Mexico.

From a point 60 miles inland from Vera Cruz to Mexico City the elevation of the land varies from 6500 to 8000 feet above sea-level. The aeroplanes with which the company was then equipped were not capable of carrying two men and a load of projectiles to a safe altitude above the mountains. For the purpose of decreasing the load the writer designed and built bomb-dropping fire-control-devices based upon the Scott instrument, but improved so that one man



would be able to fly the machine, handle the sight, and release the bombs.

To accomplish these results the following changes were made:-

A pair of longitudinal cross-wires, as well as transverse ones, were put in the sighting-tube to show when the aeroplane's path was in the vertical plane through the target. These wires took the place of the weighted wire ring.

The telescope lenses were omitted in order to permit the pilot to see the cross-wires without placing his eye close to the eye-piece, a plain brass tube being used instead of the telescope. This was sufficiently accurate for heights not greater than 5000 feet.

To eliminate the necessity for using range tables a bar was fastened to the tube parallel to the plane of the transverse wires. This bar was graduated for altitudes between 1500 and 4500 feet, and carried a sliding pointer whose index mark moved in the plane of the transverse cross-wires.

The quadrant with the degree markings was omitted and a sheet of brass substituted for it. Speed-altitude curves were engraved upon this brass sheet. These curves were plotted by polar co-ordinates, the altitudes as vectors and the time in seconds (from column one of proceeding table) in degrees.

A holder for mounting the stop-watch upon the left steering-lever was made, so that the watch could be operated without releasing the mechanism.

A similiar holder for strapping the aneroid to pilot's leg was provided.

A device was designed so that the pilot would be able to release the bombs by pressure upon a pedal.

The following was the method of operation:-

As target was approached the pilot would release the right steering-lever and set the altitude-slide at the mark on the bar that corresponded to the aneroid reading. The sighting tube would be placed at the 45 degree mark and the watch started when the point "D" crossed the wires. Tube would then be



*(To follow page No. 44)*



*PLATE NO. 9  
TOP VIEW BOMB-DROPPING FIRE-CONTROL  
DEVICE*



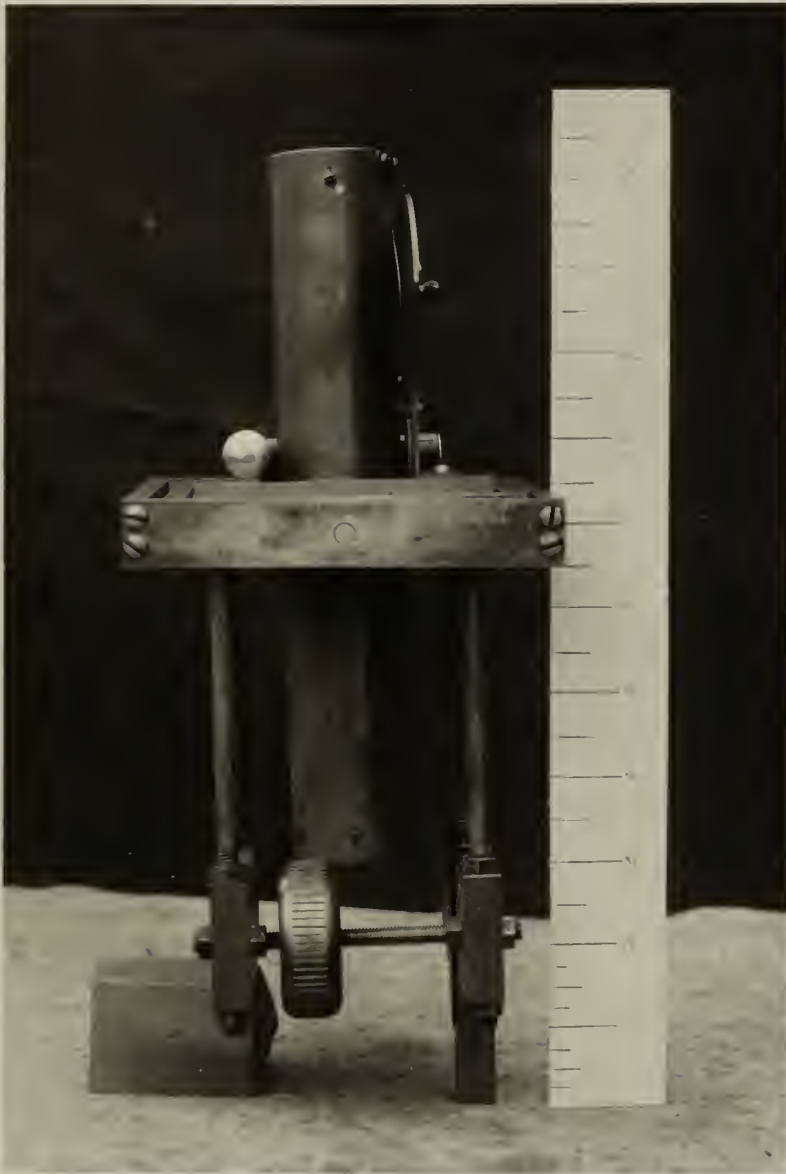
*(To follow page No. 44)*



*PLATE NO. 10*  
*SIDE VIEW BOMB-DROPPING FIRE-CONTROL*  
*DEVICE*

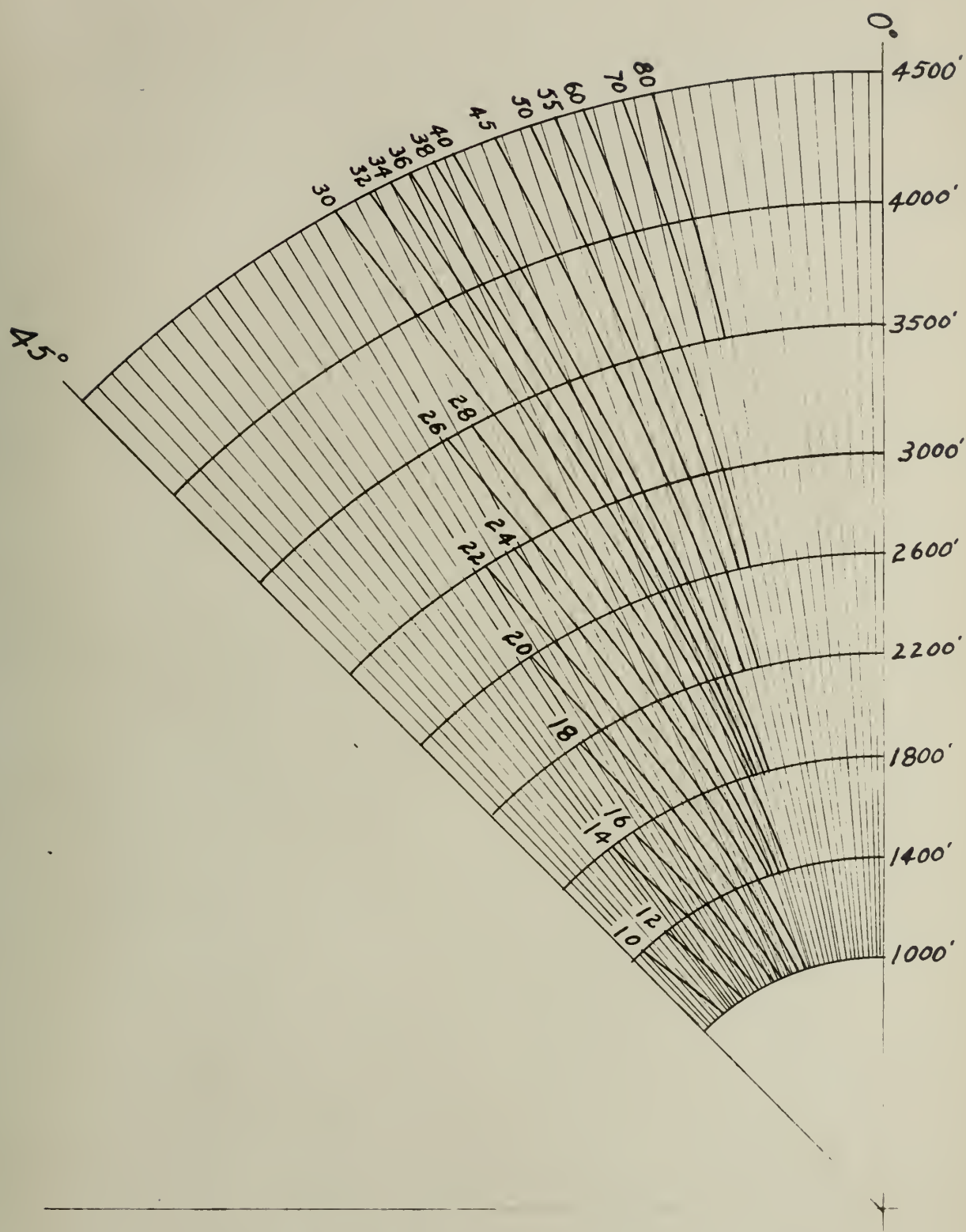


*(To follow page No. 44)*



*PLATE NO. 11*  
*REAR VIEW BOMB-DROPPING FIRE-CONTROL*  
*DEVICE*





### PLATE NO. 12

#### ANGLE-OF-SIGHT-CURVES BOMB-DROPPING-DEVICE.

*Curves are numbered to correspond to the number of seconds that is required by aeroplane to travel a distance equal to its height above target*



set at 0 degrees, or vortical, and watch stopped when "D" again crossed the wires. (See Plate No. 8 ). The time would then be read and the tube set with the index on the slide at the curve corresponding to the elapsed time. As the machine neared the target the left foot would be placed upon the release pedal and the machine steered until the planes of the longitudinal and the transverse wires passed through the target when the bomb would be released. Plates Nos. 9 , 10 , and 11 , are photographs of the instrument as constructed. (A sheet of paper was pasted over the altitude-speed curves before photographs were taken, as it is not permissible to publish these curves at this time. Lines were roughly drawn upon this paper to indicate the general shape of the concealed curves.)

Plate No. 12 is submitted to show the principles involved, the curves upon this plate being plotted from the table given below, which has been calculated in the same manner as the preceeding table in this chapter, using the formula,  $t = \frac{\sqrt{H}}{4.01}$  , and without taking into consideration the "ballistic co-efficient" of the projectile.

Time in seconds for aeroplane to travel from "A" to "B", Plate No. 8 , given at top of columns.

	10	12	14	16	18	20	22	24
Altitude.								
1000 ft.	38° 40'	33° 45'	29° 45'	26° 30'	24°	22°	20°	18°
1400 "	43° 15'	38°	34°	30° 25'	27° 40'	25° 15'	23° 10'	21° 15'
1800 "			37°	33° 30'	30° 30'	28°	25° 45'	24°
2200 "					33° 30'	30° 30'	28° 15'	26° 15'
2600 "						32° 45'	30°	28°
3000 "							32°	34°
3500 "								
	26	28	30	32	34	36	38	40
Altitude.								
1400 ft.	19° 45'	18° 45'	17° 30'	16°				
1800 "	22° 15'	20° 30'	19° 30'	18° 15'	17°	16° 30'	15° 45'	15°
2200 "	24° 30'	22° 45'	21° 30'	19° 15'	19°	18° 15'	17° 30'	16° 30'
2600 "	26° 15'	25°	23°	21° 45'	20° 45'	19° 30'	18° 30'	17° 45'
3000 "	28°	26° 45'	25°	23° 15'	22°	21°	20°	19°
3500 "	29° 45'	28°	26° 15'	24° 30'	23° 30'	22° 15'	21° 15'	20° 15'
4000 "				26° 30'	24° 45'	23° 45'	22° 30'	21° 30'



*(To follow page No.45)*



*PLATE NO. 13*  
*EFFECT OF AEROPLANE-PROJECTILE DROPPED*  
*ON HARD GROUND FROM HEIGHT OF 3000 FT.*



*(To follow page No.45)*



*PLATE NO. 14*  
*METHOD OF CARRYING LARGE PROJECTILES*



	45	50	55	60	70	80
Altitude.						
1400 ft.						
1800 "						
2200 "	14° 45'	13° 15'				
2600 "	16°	14° 30'	17° 45'	12°		
3000 "		15° 30'	14°	13°		
3500 "		16° 30'	14° 40'	13° 45'	12°	10° 30'
4000 "		17° 30'	16° 15'	14° 45'	12° 45'	11° 15'

During August and September, 1914, a series of tests was made at San Diego, California, with the sighting device, using bombs varying in weight from 15 to 100 pounds. These tests were made for the purpose of determining the accuracy of fire and the effects of the explosives. Exact results can not be published, although statements have appeared in the newspapers that "about 75 per cent of hits were made on a target 60 feet in diameter, from a height of 3500 feet." (Plate No. *13* shows the effect of a 15 pound, high-explosive bomb, dropped from a height of 3000 feet. The method of carrying the large projectiles is shown on Plate No. *14*, the bombs shown being of the 50 pound size.)

If under service conditions the accuracy of fire is not more than 50 per cent of that stated by the press to have been obtained in the above mentioned tests, it can be seen that for the purpose of raiding attacks upon large targets such as will be offered by supply-depots, bridges, fortifications, and field-batteries in place, aeroplanes with the equipment described, will be extremely valuable aggressive weapons.

The high-explosive projectile is not suited for use against troops, or other scattered objects, but is adapted for the destruction of materiel only. It has been reported that the aviators of the Allied Armies in the present European War have been able to accomplish some very valuable work in destroying bridges, tunnels, arsenals, and supply-depots of the Germans, with high-explosive bombs placed by means of the Scott device. French airmen have been using small steel darts about four inches long and one-quarter of an inch in diameter, to harass troops in the open. These darts are dropped in groups of about



1000 at a time, the retainer having been arranged to scatter the missiles over a wide area.

Although the aggressive function of the aeroplane in modern warfare, as outlined above, may be an extremely valuable one under certain conditions, its most valuable use, for at least several years, will be reconnaissance work.



## CHAPTER VIII.

## ATTACKS UPON FORTIFIED HARBORS.

The proceeding chapter has indicated a method for accurately placing missiles dropped from an aeroplane upon targets on the surface of the earth and water, and covers only the aggressive use of the aeroplane in attacks. The importance of this feature can not be expected to become greater than the "passive" assistance that the flying machine will be able to render through the supplying of information and guiding details to the fighting forces, both on land and sea.

The underwater means of attack and defense are becoming more and more important as the knowledge and use of electricity becomes greater. No naval commander would dare to enter a harbor known to be efficiently mined, nor would he attempt to "run by" harbor fortifications unless the channels were known, except in case of absolute necessity. The aeroplane is peculiarly well adapted to assist in locating submarine objects and ship-channels, for on clear, sunny days the bottom of bays and harbors not more than 100 feet deep, can be seen from heights between 1000 and 5000 feet above the surface. This fact has been known for some time but it is only within the past two years that efforts have been made to utilize this knowledge in military and naval operations.

To illustrate the value of the service that the aeroplane will be able to render the naval commander, under one phase only, an attack by a fleet upon a fortified harbor will be discussed. The fortifications may be assumed to consist of mortars, heavy guns (8" or larger), rapid-fire guns (6" and smaller), and submarine mines, with a number of fast torpedo-boats and submarines held in reserve inside the harbor.

"The strength of the fortifications will be known to the fleet commander from information collected before war broke out. As the fleet approaches within 100 miles of the harbor, the hydro-aeroplane scouts will be launched and



will scout around to guard the fleet against submarines and mines floating a few feet below the surface. Some of the aeroplanes advance to within sight of land to report on the movements of all vessels near the harbor entrance.

The fleet steams up to within dashing distance of the harbor, timing their speed so that they will arrive after dark. The aeroplanes will be able to report whether or not there are scout and patrol-boats and aeroplanes on the watch, and from this information received before dark, the chances of a surprise attack can be estimated. If the fort is on the alert, operations probably will be delayed until daylight, the fleet keeping in motion all night to lessen the danger of torpedo attack. A screen of fast destroyers will circle constantly about the battleships to ward off submarines and torpedo-boats.

At daylight the hydro-aeroplanes will ascend, fly over the fortifications, and determine not only the strength of armament but also the points at which to aim. Prominent landmarks will be selected and the location of the defenses with respect to these landmarks will be given. This information can be transmitted to the naval commander by wireless or other signalling device, or by return and personal reports of the observers.

A bombardment in force is begun, and the aeroplanes fly above the defenses and report the accuracy of fire. This bombardment will be at a range of six miles or more, and the naval gunners will be unable to distinguish their targets from the surrounding terrain, but will lay their guns to hit a point a certain number of yards from a lighthouse, building, or other easily seen object. The first shots from each ship will be "ranging shots", and after the report from the aviators is received, broadsides will be fired as rapidly as possible. Some of the aeroplanes armed with machine-guns guard against the attacks of the enemy's air-craft while the others are observing the results of fire.

If the mortars and heavy guns of the fortification are silenced and there



still remain the mine-fields and naval vessels to be encountered, the light craft steam in and sweep for mines, under the protection of the heavy ordnance of the battleships. The aeroplanes locate and plot the mines in order to lessen the danger of this work, and also guard against surprise attacks by the ships and submarines inside the harbor. As the defenders have removed all aids to navigation, the aeroplanes also have to plot the channels. (The small guns of the fort and inside vessels prevent a light-draft, lightly armored vessel from entering and sounding.)

Having cleaned the mine-fields and plotted the channels, the aeroplanes and destroyers attack the submarine-boats and torpedo-boats; the aeroplanes with bombs, and the destroyers with guns and by ramming. The heavy vessels of the fleet then enter and complete the victory.

If it was not deemed advisable to reduce the fortifications by bombardment, or if time was pressing, the naval commander might attempt to "run by", capture the city, and then destroy or capture the forts from the rear. The chief protection against a "run by" in wide mouthed harbors are the mine-fields and other submarine defenses. Ships will have been sunk, piling driven, and chains stretched to partly block the channel. Buoys, beacons, and other aids to navigation will have been destroyed or moved in the effort to delay the fleet as long as possible under the guns of the forts. False aids will probably have been placed for the purpose of causing the attacking ships to run aground within the zone of fire.

The most important things for the naval commander to know are the location of the unobstructed channel and the location of the mines, pilings, wrecks, etc. The aviators will be able to furnish this information in the following manner; the air-scouts can see the channels, plot same upon charts by the method of "bearings of prominent landmarks", and also buoy the critical points with buoys dropped from the aeroplanes. The mine-fields can be located in the same man-



ner, and it may be possible to render the mines ineffective by counter-mining with explosives dropped from above, or if the mine-control station can be located, it is destroyed and the mines rendered harmless.

After this has been done, the ships attempt to dash past the forts at full speed, steering according to the information previously received from the airmen. The aviators also send supplementary directions to the commander of the leading ship, from time to time, by wireless or visual signals. The radio-telegraph is considered unreliable for important work while the ships are under fire, for a shot may carry away the ship's receiving apparatus."

Bomb-dropping tests both in this country and abroad have proved that projectiles can be placed upon a target 100 feet in diameter from an aeroplane that is 2000 to 5000 feet high, with the Scott and similiar devices. This accuracy will not be seriously impaired by the refraction, due to the water, of the line of sight to submarine objects. To mark the location of such objects from an aeroplane, all that is necessary is to use a projectile that comprises within itself a light floating body, a heavy portion to form an anchor, a mooring-line to connect the anchor and the float, and a means of separating the float from the anchor upon impact with the water. Several different designs were made in the effort to obtain a satisfactory automatic projectile-buoy as described above. The first and simplest consisted of a float connected to a spherical iron anchor by a sufficiently long mooring-line of stranded wire. The float and anchor were connected by the loosely coiled wire and were dropped by hand, the line uncoiling as it fell, due to the greater velocity of the iron ball. The ballistic qualities of this device were so strange and wonderful that its passage through the air could be aptly compared to the antics of a dog with a can tied to its tail. Whether it would hit the target or a point several hundred feet distant was simply a matter of chance.

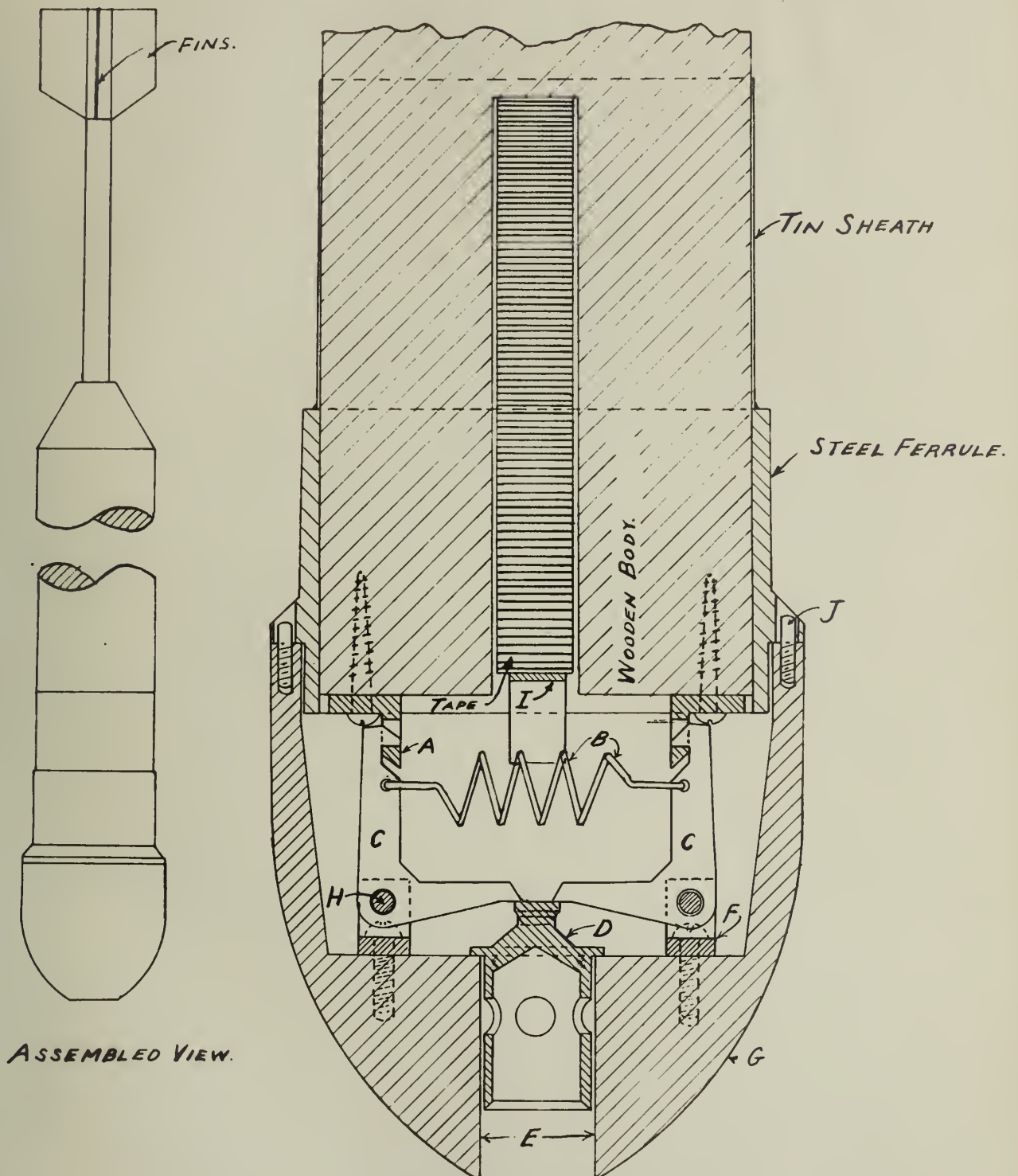
In the next design the body and anchor were fastened together forming a



round-nosed projectile, the anchor being the head. A weight inside the hollow-head was held between two springs, keeping them separated. The ends of these springs formed a latch holding the body to the head. The mooring-line was carried upon a reel in the front end of the projectile. Upon impact with the water the velocity of the projectile would be checked and the inertia of the weight would cause it to jump forward, releasing the springs. The head would then be free to continue to the bottom while the body floated, the unreeled line holding it in place upon the surface. Upon paper this design appeared feasible but in operation these difficulties were encountered. If the head was given a good shape from the ballistic stand-point, the negative acceleration upon impact with the water would be so small that it required very careful adjustment of the weight and the releasing-springs. It was also found impracticable to use stranded wire for the mooring-line on account of the difficulty of coiling it upon the small reel. Braided linen fish-line was substituted for the wire but it was not strong enough to withstand the sharp jerk necessary to start the reel in motion at the moment of separation of head and body. The last objection could have been eliminated by adjusting the release mechanism so that it would not function upon impact with the water, but would function upon striking the bottom. This adjustment could be made satisfactorily for use in less than 20 feet of water from altitudes above 2000 feet. At greater depths the impact with the bottom would not be sufficient, especially if the bottom was soft mud. At depths less than 20 feet if the bottom was soft the body would usually be buried to such an extent that it would not have enough buoyancy to force it up out of the mud.

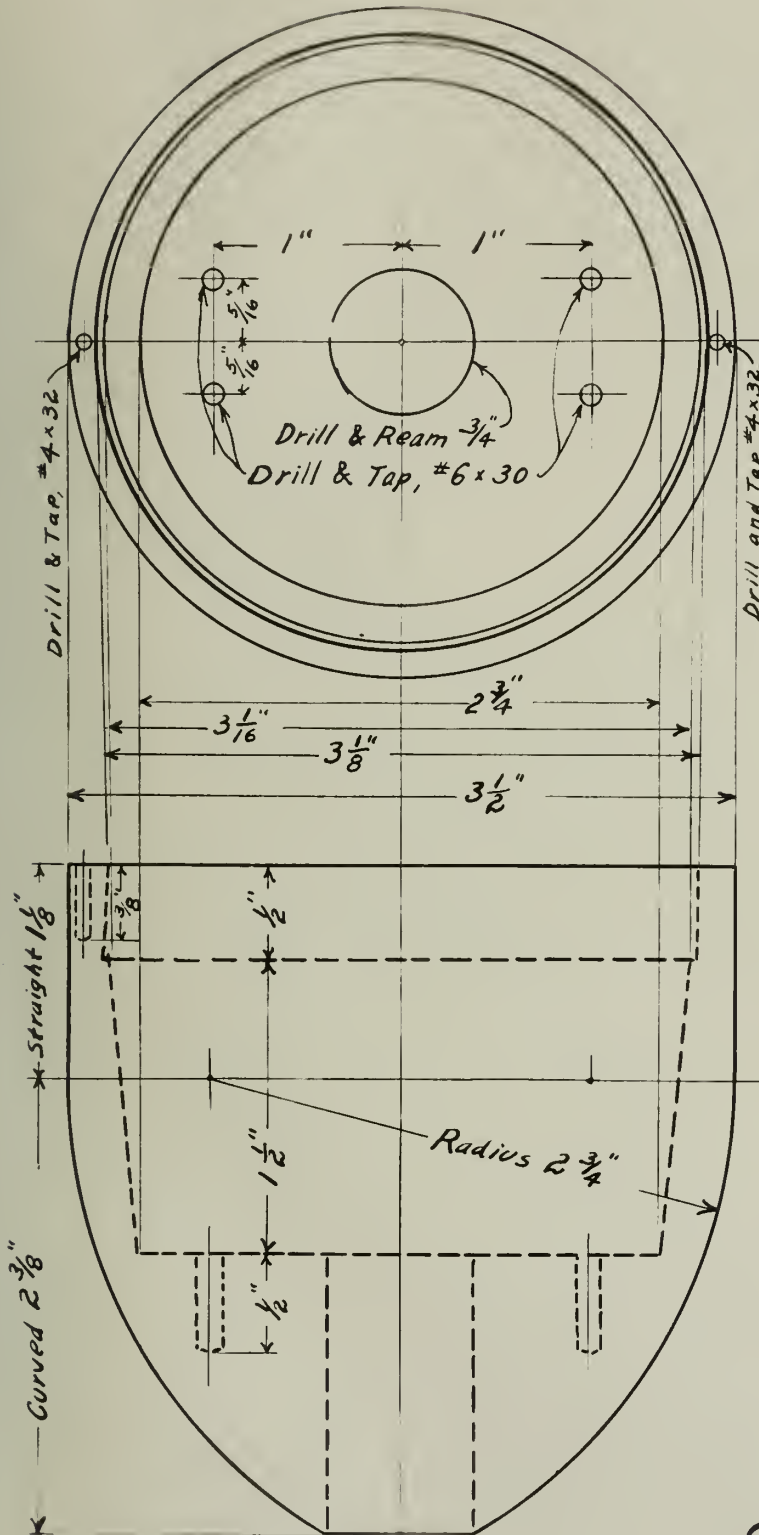
This design was discarded and a third one prepared using the projectile-shaped head and having a release device consisting of two pivoted triggers holding the head to the body. These triggers were held in place by a spiral tension-spring. A hole was drilled through the center of the nose of the anchor







(To follow page no 52).

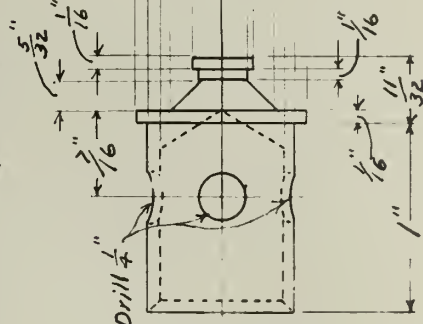
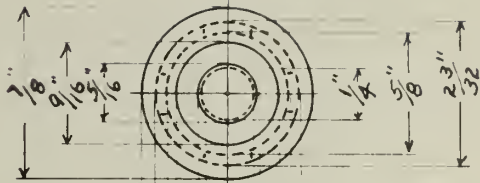


# HEAD

Material - CI or Steel.

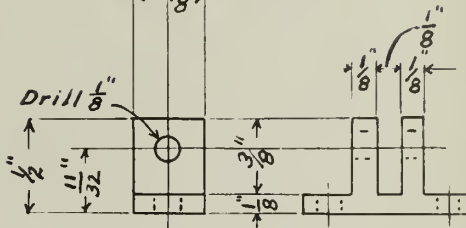
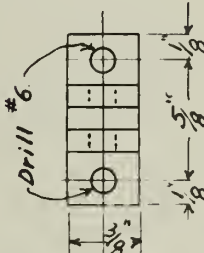
### Finish - Smooth-cut

1 Required.



*PLÜNGER.*

Material - Brass.  
Finish - All over.  
1 Required.



## TRIGGER-PIN SUPPORTS.

Material - Brass.

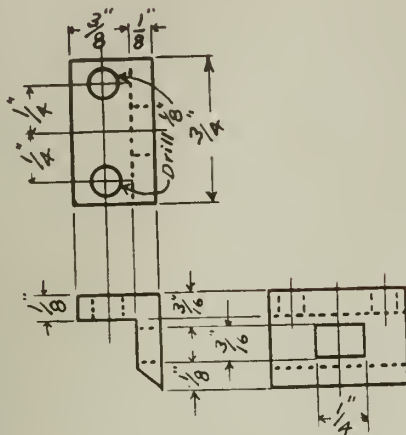
Finish - All over.  
1 Required.

PLATE NO. 16

DETAILS OF HEAD  
CHANNEL BUOY.

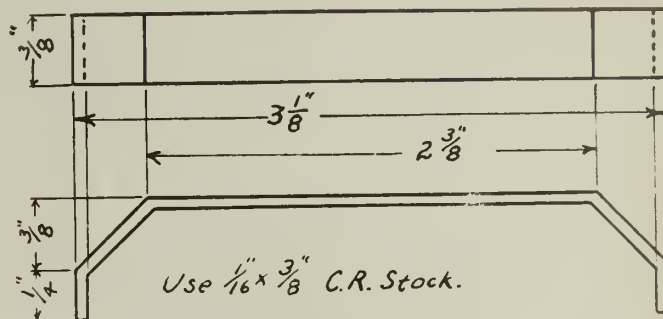
Sheet No 1





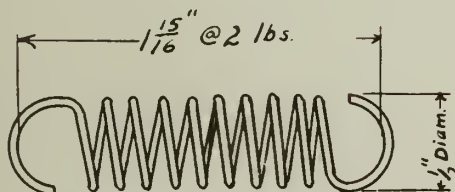
LUGS

Material - C.R. Steel.  
Finish - File.  
2 Required.



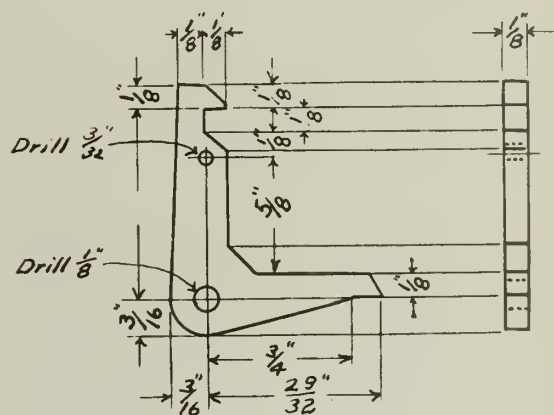
TAPE RETAINER.

Material — C.R. Steel.  
Finish — Rough.  
1 Required.



## TRIGGER SPRING

Material- Spring-Brass Wire, No.18.  
1 Required.



TRIGGER

Material - C.R. Steel.  
Finish - All over.  
1 Required.

PLATE NO. 17

DETAILS OF HEAD  
CHANNEL BUOY

Sheet No 2..



(To follow page 52).

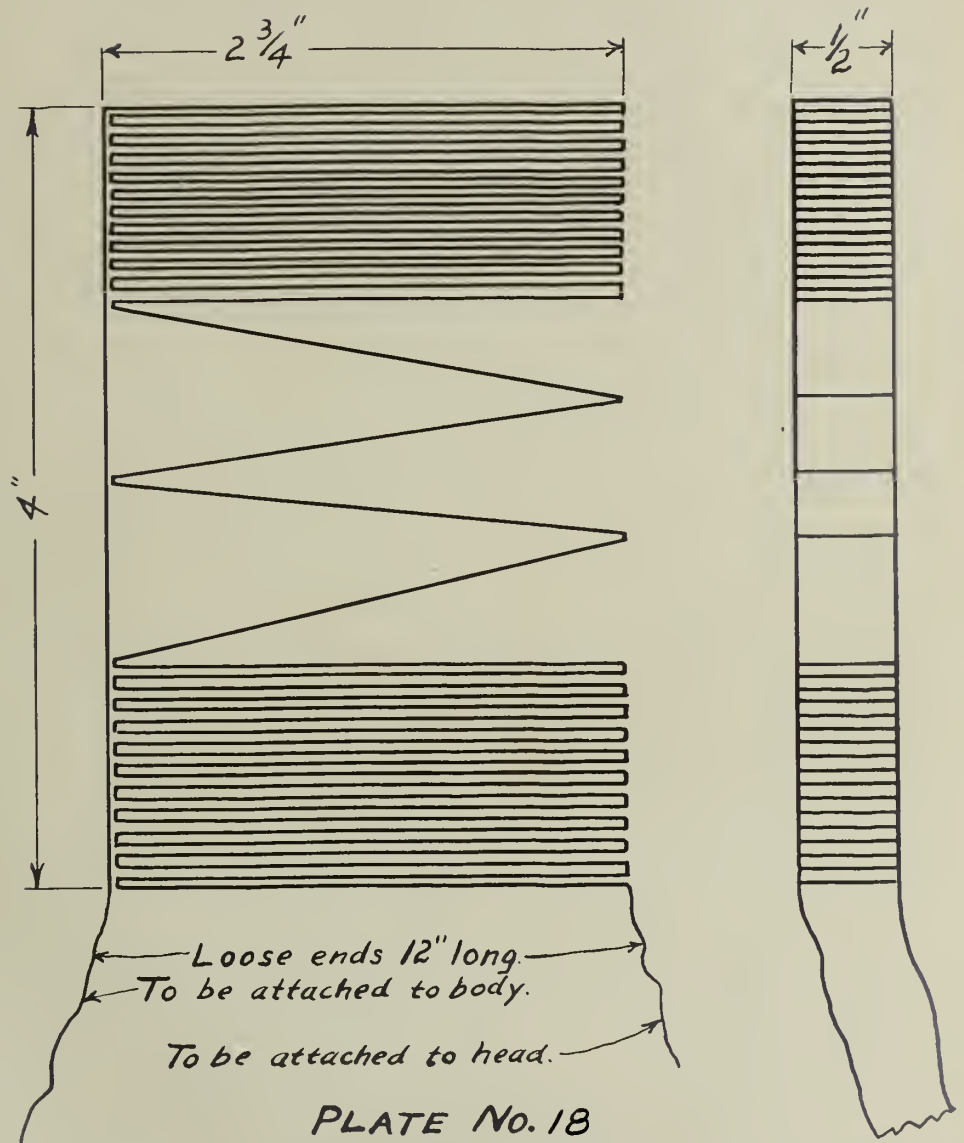


PLATE No. 18  
MOORING TAPE  
CHANNEL BUOY  
METHOD OF FOLDING  
Material -  $\frac{1}{2}$ " x 100 lb. Aeroplane - Tape  
Length - 60 ft.



and the inner end of the hole stopped by a loosely-fitting brass plunger. The inner end of the plunger bore against the free end of the triggers. The mooring-line was made of linen aeroplane-tape, folded instead of coiled or reeled. The tension of the spring was adjusted so that the air pressure on the plunger near the end of a 5000 foot fall would be insufficient to release the body, yet the impact when dropped into water from a height of 1000 feet would drive up the plunger and release the body. The plunger at the end of its up-stroke locked the triggers and prevented their re-engagement with the body-lugs, in case the parts separated slowly. The chances of quick separation were increased by drilling holes in the plunger so that after it had moved to the releasing point the water would squirt into the head and force apart the body and anchor. The details of the construction of the  $3\frac{1}{2}$ " buoy are given on Plates Nos. 15, 16, 17, and 18.

The ballistic qualities of this projectile are fairly good, the center of gravity being near the head and in front of the center of resistance. The fins on the tail add a great deal to the uniformity of trajectory and overcome any tendency to "tumbling" due to uneven working of the release mechanism. It is, however, on account of its lightness, affected more by the wind than is desirable in a projectile.

A preliminary study is being made toward adapting this buoy for night work by changing the wooden tail-rod to a thin tube filled with a slow-burning compound that would be ignited upon contact with water. For day practice the floating parts will be painted different colors to show the kind of objects that they are used to locate.

Several of the larger nations use electrically controlled submarine mines for harbor defense. These mines are connected by underwater cables to switch-board rooms on shore. To simplify and cheapen the cost of material and installation a multiple-conductor cable is laid from the shore to a point near



the mine-fields. This cable ends in a "distribution box" into which the single-conductor cable from each mine is led. This box is large enough to be visible from a height of several hundred feet, if newly placed, as it would be at the beginning of hostilities. The cables also can be seen under favorable conditions. If the cables are cut the mines are rendered harmless. The most successful method of counter-mining is to grapple and cut the multiple-conductor cable, using small boats for the purpose. To accomplish this successfully, the defender's guns must be silenced. The problem of mine-sweeping, even under the most favorable conditions, is one that requires the exercise of the highest type of skill and daring, and under fire, it is almost beyond the limits of human endurance.

The aviator can assist by decreasing the danger due to lack of knowledge of the exact location of the mines and cables. The problem of destroying the distribution box and the cables by the use of high-explosive projectiles dropped from an aeroplane, with delayed-action fuses is being studied. At the present time it appears that a partly successful solution will be obtained, adding another item to the already multifarious duties of the military flyer.

The history of warfare teaches that whenever an offensive weapon is invented some defensive device will be supplied to counter-act or resist it. This holds true concerning the utilization of the aeroplane in connection with the attacks upon submarine mines, and the aeroplane itself becomes an instrument of defense. Its defense may be "aggressive" by machine-gun fire upon attacking aeroplanes, or "passive" by aiding in the concealment of the objects of attack. It has been the custom of some of the leading nations to use galvanized iron cases for containing the explosive charge of submarine mines, and as these are not visible from on board ship if the mine is ten or more feet beneath the surface, there has been no necessity for concealment beyond that offered by the water. As soon as it was learned that mines were visible from an aeroplane



flying above the zone of effective fire, steps were taken to protect the mines by coloring them so that they could not be distinguished from the background. Naturally, the first step was to determine the color of the bottom of the mine-field, and the aviator was called upon to do this.

A color card of thirty shades was prepared with water-color paints, the different shades being numbered. Charts of the areas to be investigated were marked into squares, these squares being 200 yards on each side. Bearings of landmarks were also placed upon the cards to assist in locating important sections. The observer would then ascend and fly over the mine-field, comparing and matching the colors on the card with the appearance of the bottom inside each square, and marking upon the chart the number of the corresponding colors. After alighting, the chart would be tinted to match the colors upon the reference card. Flights would be made on different days in order to obtain the varying light effects, and after the chart was completed, it would be taken up and compared by different observers. In some cases several observers would prepare separate charts, and then compare them. Where radical differences occurred, flights would be made to locate the errors. By this method the personal equation would be partly eliminated. After satisfactory charts were obtained, the mines were painted as nearly as possible the same color as the bottom above which they were to be placed. These mines were planted, and observers viewed them from above. The less experienced men had difficulty in seeing the mines, while the trained men were often able to locate them very easily. For quite a while this result was very puzzling as well as discouraging. After investigation it was found that the trained men did not actually see the mines, but saw their shadows upon the bottom. The mines had sharp outlines, and the shadows cast were sharp and distinct. This condition can be easily eliminated by giving the mines an irregular outline, attaching pieces of tin, rope-ends, etc., coated with the protective coloring, to the cases. This



should result in a mine-case that will be extremely difficult to see and which will cast an irregular, broken shadow that blends with the bottom. If these conclusions are born out in practice it will undoubtedly cause a radical change in the present system of submarine mine defense.



## CHAPTER IX.

## FIELD SHOP.

The aeroplane is necessarily one of the most delicate of the devices used in modern warfare, and the very nature of the work which it must perform renders it liable to breakage and damage, even under the most favorable peace conditions, and the likelihood of injury will be greatly multiplied during the conditions that will exist in a campaign. It is, therefore, necessary that means be provided for making repairs, at least minor ones, to the planes and motors while in the field. Tools, supplies, and spare parts can be transported with the army trains, and a great many of the repairs made from the spares carried. A great many probable breakages can not, however, be replaced with new parts, and it has been found necessary to do a certain amount of machine-tool work in the field.

From observation of the tools that are most frequently used for maintaining the aeroplanes and their accessories in serviceable condition, it has been learned that the needed equipment could be consolidated into a very small space for transport, and that it would be possible to furnish such an equipment within the maximum weight limit of the load that could be hauled by an auto-truck over poor roads, and even across firm turf.

An engine-lathe with its attachments, a drill-press, and a precision-grinder are believed to be the only machine tools that will have to be power-driven. The question of furnishing the power for these tools was investigated very carefully, and it was decided that the most suitable plant would be a self-contained portable gasoline-electric generator-set. This decision was made because the necessity of shafting and its accompanying defects and troubles would be eliminated, and because a means of furnishing light for night work would be available in a light, compact, easily-handled form.

The shop must be an entirely independent unit, suitable for quick trans-



portation by truck, wagons, or pack animals. The maximum load that can be carried by a mule is 350 pounds, and this item places a definite limit to the weight of the heaviest single piece. The smallest lathe that will be able to do the required work has a 9 inch swing and a 5 foot bed. As there will be occasion for milling and slotting, a milling attachment for the lathe must be provided. The lathe selected weighed, with chucks and other attachments, 480 pounds, when arranged for bench-mounting. As this weight is greater than a mule can pack, provision was made for stripping all easily removable parts from the lathe-body. Other parts that had no bearing upon the accuracy of the tool, such as cone-pulleys, gear-cases, etc., were made of aluminum.

The lathe-bench is to be made in sectional-cabinet form, and will consist of two parts, one containing motor, chucks, face-plates, dogs, etc., and the other the milling attachment and small tools. The lathe-body will be bolted to a bench, and provided with a light wooden cover.

For transportation the complete lathe and equipment will consist of three boxes, the heaviest weighing about 310 pounds. The power drill-press, drills, and clamps will be packed in a cabinet for transport, the top of the cabinet forming the bench for mounting the drill while in use. The precision-grinder with its wheels also forms a separate unit, and will have a small hand drill-press packed in the same cabinet with it. A portable army-type forge and a small anvil, with the necessary blacksmith's tools will form another unit. Three small chests will contain the required hand-tools. A gasoline brazing-torch, hand-grinder, taps and dies, etc., will be the contents of another cabinet. It is planned to carry stock of assorted bolts, screws, and nuts in a case with compartments for the different sizes. The stock of steels, brass, bronze, etc., will be cut into five-foot or shorter lengths, and will be carried in narrow boxes.

The generator-set has not yet been purchased but it is believed that a



compact, two-cylinder,  $1\frac{1}{4}$  kilowatt, 110 volt direct-current, direct-connected unit, similiar to those manufactured for marine work, will be selected. The plant under consideration weighs 250 pounds without fuel, oil, or water.

Although the drawings are not completed, enough has been done to show that it will be possible to place the required equipment, tentage, and personal effects of the shop force (four men), upon one truck. The truck body will be 6 feet wide and 12 feet long and will be with hinged sides, to form additional work-benches when lowered. The total weight of the load will be approximately 3400 pounds.

The shop will not be arranged to permit working while truck is loaded, it being the intention to place equipment beneath a tent and leave truck free for other uses while in camp.

It will be necessary to use two standard army-wagons or twenty pack-animals to transport shop in case the truck is disabled, or in case the roads or trails are impassible for power-driven vehicles.

The field shop, although a problem in engineering, is not one that can be entirely worked out upon the drafting board, and like a great many of the other features connected with military aviation its correct solution requires the combination of theory, experiment, and actual test under service conditions.

Although but a few of the many and varied features of military aviation have been briefly outlined in the preceeding chapters, it can be seen that its progress is dependent, not only upon the application of the principles of aerodynamical, but also upon other branches of engineering.





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